

THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MAJOR ACTIVITIES IN THE NASA PROGRAMS

FACILITY FORM 502

N 66-82619

(ACCESSION NUMBER)

189

(PAGES)

TM-X 57349

(NASA CR OR TMX OR AD NUMBER)

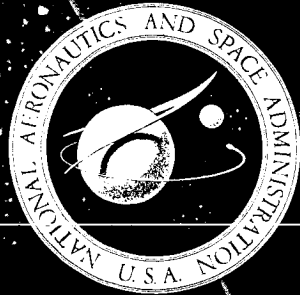
(THRU)

none

(CODE)

(CATEGORY)

★ OCTOBER 1, 1959—
★ MARCH 31, 1960

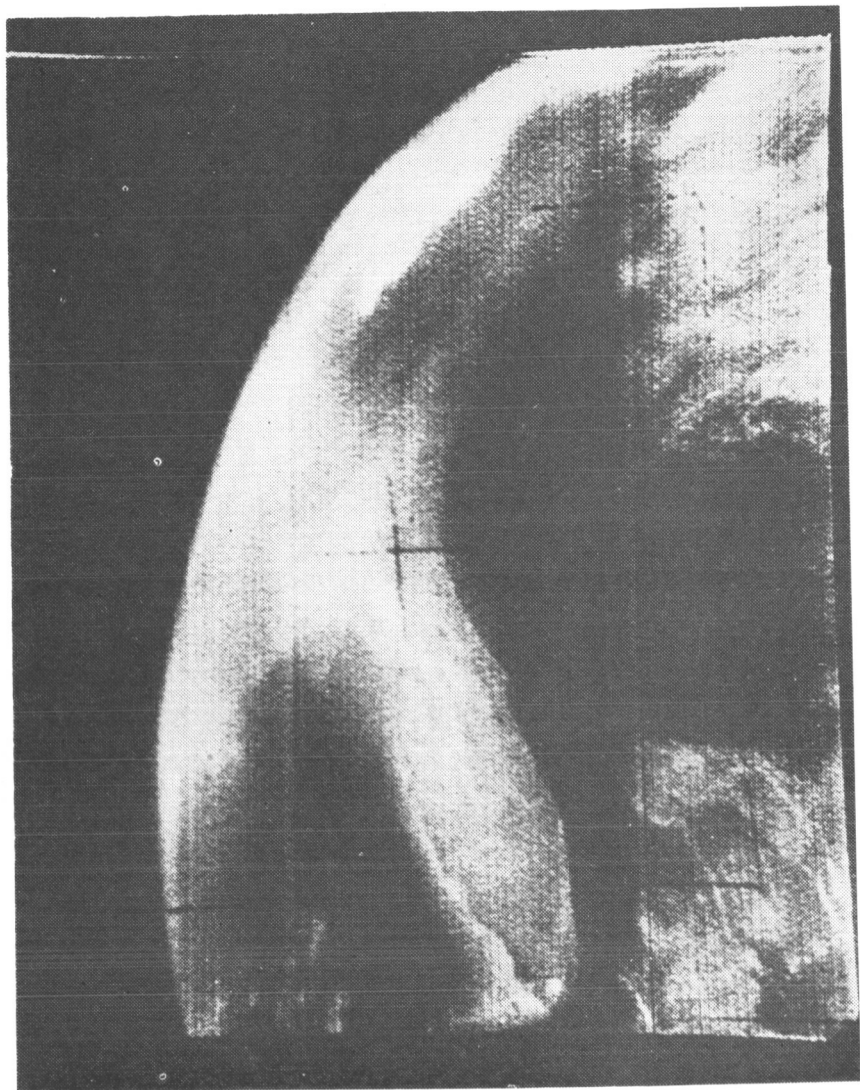


1520 H STREET N.W.
WASHINGTON 25, D.C.

MAJOR ACTIVITIES
IN THE
PROGRAMS
OF THE
NATIONAL AERONAUTICS AND
SPACE ADMINISTRATION



October 1, 1959 – March 31, 1960



This photograph, taken by the wide-angle camera in the TIROS I meteorological satellite, clearly shows the Florida peninsula and adjacent areas.

FOREWORD

Herein are recounted major activities of the National Aeronautics and Space Administration from October 1, 1959, through March 31, 1960, the third half-year period since NASA came into being.

This publication comprises: 1) an introductory chapter which summarizes the status of current NASA programs and briefly outlines long-range planning; 2) a detailed, 17-chapter discussion of progress in NASA aeronautics and space research and development; and 3) fourteen appendices that include memberships of principal Congressional and NASA committees, an analysis by the NASA Bioscience Advisory Committee of the role of the life sciences in space exploration, lists of research grants and contracts and research and development contracts, and the NASA financial statement for the period.

CONTENTS

	Page
Chapter 1—Introduction	1
Summary of progress	1
Major programs	1
Space flight	1
Aeronautical research	2
International programs	2
NASA's long range plan	2
Launch vehicle development	2
Long range plan missions	3
First Mercury suborbital flight	3
Moon landings planned	4
Planetary missions	4
Committee on Long Range Studies	4
Chapter 2—NASA highlights (Oct. 1, 1959, through Mar. 31, 1960)	5
Chapter 3—Experimental missions	9
Major experiments	9
Explorer VII measures Earth's radiation	9
Heavy primary cosmic ray results	12
Low energy particles experiment	12
Micrometeoroid experiment	13
Satellite temperature experiment	13
Pioneer V orbits the Sun	14
TIROS I launched	17
Lunar satellite attempt	21
Radiation satellite attempt	22
Aerobee 150-A's launched from Wallops	22
X-248 engine flight-tested in Javelin	22
Nike-Asps launched	22
Sodium flare experiments launched	23
Table—NASA satellites, lunar probes, and space probes	24
Chapter 4—National launch vehicle program	28
Scout	28
Delta	29
Atlas-Agena B, Thor-Agena B	30
Vega canceled	30
Atlas-Centaur	31
Saturn	32
F-1 engine	34
Sounding rocket development	35
Arcon	35
Iris	35
Chapter 5—Manned flight in space and near space	36
Project Mercury	36
Suborbital flight planned	36
Redstone will launch capsule	36
Orbital flight plan	36
Progress during report period	38
Little Joe flight tests	38
McDonnell delivers first capsule	39
Capsule escape and retrograde rockets	41
Parachute tests carried out	41
Environmental control system tests	41
Astronaut pressure suits delivered	42
Attitude sensing and reaction control systems	42
Communications (on-board) and instrumentation	42
Big Joe flight test results	42
Astronaut training progresses	44
Mercury tracking network progress	46

	Page
Chapter 5—Manned flight in space and near space—Continued	48
The X-15 research airplane	48
Plane No. 1 transferred to NASA by contractor	49
X-15 No. 2 reaches new peak altitude	49
Demonstration flights continued	49
XLR-99 engine ground tests	50
Chapter 6—Space sciences research	50
International science activities	50
First international space symposium	51
Explorer VII telemetering codes released	51
Scientific results to date	51
Nature of radiation region still conjectural	51
Earth's magnetic field relatively stable	52
Hazards to life and spacecraft evaluated	52
Sunlight pushes first Vanguard	52
Earth's pear shape confirmed	52
Radiation affects weather	52
Space research programs	53
Satellites and sounding rockets	53
Geophysics and astronomy	53
Atmospheric veil pierced	53
Scope of geophysical investigations	53
The atmosphere	54
Atmospheric structure satellite	54
Sounding rocket activities	54
The ionosphere	55
Direct ionospheric measurement by satellite	55
Ionosphere beacon satellite	55
Topside sounder	55
Electron density probes	56
Energetic particles	56
Radiation satellite experiments	56
Sounding rocket activities	56
Project NERV	57
Project SBE (Solar Beam Experimental)	57
Magnetic and electric fields	57
Astronomy	57
Program scope	58
Gamma ray astronomy satellite	58
Gamma ray telescope	58
Solar spectroscopy satellites	59
Orbiting astronomical observatory	59
Supporting and related activities	60
Theoretical work	61
Chapter 7—Satellite applications	61
Meteorological satellite programs	62
Communications satellite (Project Echo)	66
Chapter 8—Lunar, planetary, and interplanetary programs	66
Space exploration: Second phase	66
Scientific goals	67
Schedule criteria	67
Lunar missions	67
First step: Instrumented lunar orbiters	68
Second step: Controlled landings on the moon	68
Lunar-impact missions	69
Soft landings	69
Planetary and interplanetary missions	70
Chapter 9—International programs	70
Tracking network negotiations	70
Cooperation in space research	70
Discussions with Soviet scientists	70
Tracking services offered Soviet Union	70
Dissemination of technical information	71
Cooperative space programs	71
First international space science symposium	71
Grants to foreign scientists	71

CONTENTS

VII

	Page
Chapter 9—International programs—Continued	72
International cooperation through the United Nations	72
Background	72
Permanent U.N. Committee on Peaceful Uses of Outer Space established	72
NASA prepares for conference participation	72
Chapter 10—Tracking and data acquisition	73
Role in space program	73
General objectives and description	73
Minitrack network	73
Description and operation	73
Network being extended	74
Equipment improvement	74
Conversion of tracking frequencies	74
Optical tracking	75
Description	75
Operations	75
Deep space network	76
Goldstone transmitter completed	76
Advanced technical programs	76
Mercury network	76
Projected locations	76
Construction	77
Negotiations	77
Wallops Station, Va.	77
Complete local tracking and telemetry system	77
Major projects	77
Additional tracking equipment installed	77
Cooperating stations	77
Supplement current capabilities	77
Phototrack stations	78
Telemetry stations	78
Overall developments	78
Consolidation of ground communications	78
New frequency assignments	78
Computation and data reduction	78
Chapter 11—Propulsion and nuclear energy applications for space	80
Space propulsion	80
Types of research facilities used	80
Chemical rockets	80
Fuel-oxidizer research	81
Hydrogen-fluorine engine	81
Physics and chemistry of combustion	81
Rocket-engine exhaust nozzles	83
"Plug nozzle" for rocket engines	83
Problems in pumping cryogenic fluids	85
Storage of cryogenic propellants during space missions	85
Gas generators for turbopump systems	86
Turbopump systems investigations	86
Liquid hydrogen pressurization studies	87
Solid-propellant rockets	87
High-performance rocket motors	87
Large boosters	88
Steering and velocity control	88
Thrust modulation	89
Materials and manufacturing techniques	89
Electric rockets	89
Development of electrical propulsion systems	90
Ion rockets	90
Plasma rockets	91
Electrothermal rockets	91
Use of solar radiation for propulsion	92
Nuclear energy applications for space	92
Nuclear heat transfer rockets	92
Power generation	95

	Page
Chapter 12—Materials and structures.....	96
Problems of extreme temperatures.....	96
Alloys for high-temperature applications.....	96
Refractory metals.....	97
Refractory ceramics.....	97
Improving heat-resistant alloys and refractory metals.....	98
Nozzle materials for solid-propellant rockets.....	98
Bearings for use at cryogenic temperatures.....	99
Other materials studies.....	99
Effects of nuclear radiation on metals.....	99
Studies of fatigue strength.....	99
Ablation materials.....	100
Chapter 13—Mechanics of space flight.....	101
Extreme conditions involved.....	101
Control and stabilization.....	101
Piloted space vehicles.....	101
Simulated space flight.....	101
Ames 5-degree-of-freedom simulator.....	102
Langley fixed base simulators.....	102
Three-axis simulator investigations of signals.....	103
Adaptive control system.....	104
Guidance and navigation.....	104
Entry corridor possibilities.....	104
Trajectories.....	105
Computer use.....	105
Precise and simplified calculations.....	105
Mars and Venus trajectories.....	105
Investigation of lunar "soft" landing techniques.....	106
Midcourse trajectory corrections.....	107
Chapter 14—Aerodynamics, fluid mechanics, and environmental physics.....	108
Aircraft aerodynamics.....	108
Flying qualities of helicopters and VTOL aircraft.....	108
Supersonic-transport aircraft.....	109
Multimission aircraft.....	109
Fluid mechanics.....	110
Physics and chemistry of gases at high temperature.....	110
Interactions of ionized gases.....	110
Space environment physics.....	111
Micrometeoroid impacts studied.....	111
Photochemistry of upper atmosphere gases.....	112
Ion beam experiments.....	112
Chapter 15—Flight Safety.....	113
Operations and environment.....	113
Studies of altimetry problems in airplane operations.....	113
Downwash effects on VTOL aircraft.....	114
Noise sources on supersonic transports.....	114
"Wake" effects of large transport aircraft.....	115
Fuel sloshing dampers.....	115
Power-off landing for low lift-to-drag ratio vehicles.....	115
Measuring physiological conditions of pilots.....	116
Measurements of winds and wind shears.....	117
Other studies.....	117
Chapter 16—The NASA organization.....	118
Organizational development.....	118
Spaceflight functions reassigned.....	118
Launch vehicle program broadened.....	118
Office of Launch Vehicle Programs.....	118
Office of Space Flight Programs.....	118
Office of Aeronautical and Space Research reorganized.....	119
Office of Life Sciences Programs.....	119
Office for the United Nations Conference established.....	119
Office of Associate Administrator reorganized.....	120
George C. Marshall Space Flight Center established.....	120
Space flight centers specialize.....	121

CONTENTS

IX

Chapter 16—The NASA organization—Continued	Page
Structure and functions.....	121
NASA organization chart.....	Facing 121
Langley Research Center.....	121
Ames Research Center.....	121
Lewis Research Center.....	122
Flight Research Center.....	122
George C. Marshall Space Flight Center.....	122
Atlantic Missile Range (AMR) Operations Office.....	122
Map—Locations of NASA installations.....	123
Western Operations Office.....	124
Goddard Space Flight Center.....	124
Wallops Station.....	124
Jet Propulsion Laboratory (JPL).....	124
NASA relations with other Government agencies.....	125
Chapter 17—Personnel.....	126
Composition and growth of NASA staff.....	126
Recruiting, examining, and training.....	126
Recruiting and examining.....	126
Table—Distribution of NASA personnel.....	127
Training programs.....	127
High school liaison.....	127
Employees honored.....	128
Chapter 18—Other activities.....	129
New and continuing work.....	129
Procurement and contracting.....	129
Realinement in organization.....	129
Decentralization progress.....	129
Small business program.....	130
Types of contracts.....	130
Cooperative procurement agreements.....	130
Procurement regulations promulgated.....	130
Research grants and contracts.....	130
Sixty-eight awards.....	130
Description.....	131
Patent program.....	131
Patent waiver regulations.....	131
Establishment of patent counsel for research centers.....	131
Protection of NASA inventions.....	131
Patent infringement.....	131
Review of patent applications.....	132
Reporting of inventions by contractors.....	132
Inventions and contributions.....	132
Functions of the Inventions and Contributions Board.....	132
Contributions awards.....	132
Waiver petitions granted.....	133
Construction and equipment.....	133
Langley Research Center, Hampton, Va.....	133
Ames Research Center, Moffett Field, Calif.....	134
Lewis Research Center, Cleveland, Ohio (including Plum Brook Facilities, Sandusky, Ohio).....	135
Flight Research Center, Edwards, Calif.....	136
Jet Propulsion Laboratory, Pasadena, Calif.....	136
Goddard Space Flight Center, Greenbelt, Md.....	137
Wallops Station, Wallops Island, Va.....	138
Marshall Space Flight Center, Huntsville, Ala.....	139
AMR, Cape Canaveral, Fla.....	139
Tracking and data acquisition stations.....	139
Public and technical information.....	140
Public information.....	140
Technical information.....	141
Appendix A—Memberships of Congressional committees.....	143
Appendix B—Membership of the National Aeronautics and Space Council.....	143
Appendix C—Membership of the Civilian-Military Liaison Committee.....	144

	Page
Appendix D—Membership of Lunar Science Group.....	144
Appendix E—Membership of Special Committee on Life Sciences.....	145
Appendix F—Membership of Joint (AEC-DOD-NASA) Committee on Hazards of Space Nuclear Systems.....	145
Appendix G—Membership of Committee on Long-Range Studies.....	145
Appendix H—Membership of Inventions and Contributions Board.....	146
Appendix I—Membership of the NASA-DOD Space Science Committee..	146
Appendix J—Research Advisory Committees.....	146
Appendix K—Report of the Bioscience Advisory Committee.....	154
Appendix L—Research grants and contracts.....	169
Appendix M—R. & D. contracts or amendments thereto of \$100,000 and over shown by program.....	174
Appendix N—Financial statement as of March 31, 1960.....	180

MAJOR ACTIVITIES IN THE PROGRAMS OF THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

CHAPTER 1

INTRODUCTION

SUMMARY OF PROGRESS

Between October 1, 1959, and March 31, 1960, the agency completed and set in motion a long-range plan of space exploration spanning the 1960-70 decade.

At the same time, NASA's research, space flight, and aeronautical programs moved ahead and major organizational changes were effected to accommodate increased responsibilities in the field of launch vehicle development.

On January 14, 1960, the President notified the Congress of his intention to transfer to NASA the Development Operations Division of the Army Ballistic Missile Agency at Redstone Arsenal, Huntsville, Ala., along with Saturn, the 1.5-million-pound-thrust clustered rocket engine under development by the Division. The transfer became effective 60 days after notification and the budgetary transfer will be completed by July 1, 1960. On July 1, NASA will assume responsibility for the Division's facilities and 1,200 acres at the arsenal—which the President has renamed the George C. Marshall Space Flight Center.

To speed development of launch vehicles, and to make the most effective use of the Huntsville group, NASA created an Office of Launch Vehicle Programs late in 1959 and other major divisions were realigned as follows: The Office of Space Flight Programs, the Office of Advanced Research Programs, the Office of Business Administration, and the Office of Life Sciences Programs.

The Saturn rocket shares top NASA priority with Project Mercury, first phase of the manned space flight program. Project Mercury progress included delivery by the contractor of the first operational Mercury space capsule on April 1.

MAJOR PROGRAMS

SPACE FLIGHT

Sustained by vigorous research and development in space sciences and space technology, NASA's space flight program was marked by three particularly significant experiments—the Explorer VII satellite; the Sun-orbiting Pioneer V deep-space probe; and the TIROS I experimental meteorological satellite which has transmitted 22,952 photographs of the Earth's cloud cover.

AERONAUTICAL RESEARCH

In the realm of aeronautics, research continued across the speed range from hovering flight to the near-satellite velocities of the rocket-boosted Dyna-Soar I, under development by the Air Force. Between these speed extremes, NASA, in cooperation with the Air Force and Navy, continued to place strong emphasis upon the X-15 rocket-powered research airplane project. Final contractor tests for the first X-15 were completed and the airplane was transferred to NASA on February 9. NASA and USAF pilots have been flight-testing the airplane since that time. In addition, NASA is studying a number of vertical takeoff and landing (VTOL) and short takeoff and landing (STOL) aircraft. Supersonic transport concepts are also being investigated.

INTERNATIONAL PROGRAMS

In the field of international cooperation, NASA concluded agreements for establishing Project Mercury tracking stations in Australia and in Spain's Canary Islands. NASA also offered the services of its tracking stations—subject to the consent of the host countries—to the Soviet Union for any manned space flight program it may develop, and established the Office for the United Nations Conference to represent the United States in a conference on the peaceful uses of outer space.

NASA'S LONG-RANGE PLAN

NASA's overall mission, as outlined in the National Aeronautics and Space Act of 1958, is to exploit the earth's atmosphere and outer space for peaceful purposes and to provide aeronautical and space research support to the armed services at the same time. In producing a long-range plan, NASA is translating into operational terms the objectives set forth in the act calling for—

the preservation of the role of the United States as a leader in aeronautical and space science and technology and in the application thereof to the conduct of peaceful activities within and outside the atmosphere * * * .

LAUNCH VEHICLE DEVELOPMENT

Foundation stone of the long range plan is development of a small family of versatile, highly reliable launch vehicles to power spacecraft on a wide variety of orbital and space-probing missions. Scout and Delta, which were flight-tested for the first time shortly after this period ended, are the smallest vehicles in the family.

In the medium- to high-thrust class is the Atlas-Agena B which the Department of Defense will launch this year and make available to NASA to replace the Vega which NASA canceled on December 11, 1959. A still more advanced, higher thrust vehicle is the Atlas-based Centaur with its liquid-hydrogen second stage. The first Centaur launching is planned for 1961. When fully developed, it will be capable of sending some 8,500 pounds into an Earth orbit.

In the high-thrust vehicle range, NASA has begun static testing (that is, running the engines with the vehicle clamped, in a vertical position, to its launch pad) the 1.5-million-pound-thrust Saturn first stage multichambered engine.

With Saturn, NASA will lay the groundwork for manned exploration of the moon. Saturn will be capable of circumnavigating the moon and returning to earth, and of launching a 25,000-pound space laboratory into an earth orbit. During the next few years, NASA will be flight-testing various Saturn stages and in 1964 the first three-stage vehicle will be launched.

Toward the end of the 1960's, NASA expects to have a launch vehicle in the Nova class which may consist of a cluster of F-1 single-chamber engines, each producing 1.5-million pounds of thrust. By clustering these engines, which are now under development, it would be possible to achieve a total thrust of 6 to 12 million pounds. Alternatively, the very large capacity of the system might be achieved through the use of nuclear energy.

Nova will probably be the first vehicle with which the United States will attempt to land men on the moon. Now in the concept stage, it should be capable of carrying 100,000 pounds to the Moon and of placing a 290,000-pound space laboratory, occupied by several individuals, in an Earth orbit.

Nuclear propulsion systems, which are now a subject of active research and development in cooperation with the Atomic Energy Commission, will be developed over this decade for important roles in the space program.

LONG RANGE PLAN MISSIONS

The successful operation of TIROS I was the first event on NASA's list of specific missions in the long range plan. TIROS I will be followed by other experimental weather satellites of similar type. These will be followed by the more advanced Nimbus series.

Also scheduled for 1960 is the first launching in Project Echo of a 100-foot-diameter, inflatable "passive reflector communications satellite." The ultimate purpose of these orbiting spheres, made of microthin aluminized Mylar plastic, is to serve as global teleradio transmission links. A series of such satellites may one day revolutionize worldwide communications and make transoceanic TV a reality.

In April, NASA achieved the first completely successful suborbital test flight of an Echo sphere and transmitted voice and radio signals via the sphere. (Radio transmitters on the ground beam electromagnetic waves at the satellites which, in turn, reflect or "bounce" them back to another ground station.)

FIRST MERCURY SUBORBITAL FLIGHT

Near the year end (1960), the United States plans to send up an astronaut on the first suborbital flight in Project Mercury. A Redstone rocket will launch him in a Mercury capsule from Cape Canaveral on a 15-minute flight down the Atlantic Missile Range at speeds up to 4,000 miles per hour. He will experience about 5 minutes of weightlessness, reach an altitude of 100 miles and a distance of 180 miles, and will land in the sea off the coast of Florida.

During the next 2 to 3 years, NASA has scheduled 20-odd testing, training, and orbital flights in Project Mercury. The first manned orbital flight should take place in 1961.

MOON LANDINGS PLANNED

During the 10-year period, the United States will press forward with its lunar exploration program, which will consist of step-by-step progress through a series of experiments, each designed to extend our knowledge and capabilities. First attempts will be lunar orbiters, followed by so-called "hard" landings of scientific data-gathering instruments. Next will come "soft" landings on the moon with more fragile instruments. NASA may land mobile instrument stations on the lunar surface, powered by solar batteries.

The most rewarding phase of lunar exploration will come when men reach the moon, probably after 1970. In a broad sense, the main drive of the long range plan consists of preparation for manned expeditions to the moon and nearby planets in the decades to follow. The United States is placing emphasis upon lunar experiments for several reasons:

First, in the words of a scientist in NASA's lunar program:

The moon may have the answers to some of the most important questions in science. How was the solar system created? How did it develop and change? Where did life come from?

The particular importance of the moon is that it is the only accessible object that can give us these answers. The reason for this is that the moon has no wind and water to erode its surface, to wear away the record of history, to destroy the cosmic dust that has fallen there for billions of years * * *

Second, success in the lunar program will provide this country with the experience for attempting flights to the nearer planets. In short, NASA will be able to perfect its communications, guidance, and propulsion systems over the lunar distance—about a quarter of a million miles—and thus get "practice" for the longer voyages to Venus and Mars.

PLANETARY MISSIONS

The planetary missions have as their scientific objectives the study of the origin and evolution of the solar system; the study of the nature of planetary surfaces and atmospheres; and the search for life.

PLAN IS SUBJECT TO CHANGE

Any plan projecting research and development activities as far as 10 years ahead is, of course, subject to continuing review and change.

COMMITTEE ON LONG RANGE STUDIES

On a broader, more general scale, the agency has established a Committee on Long Range Studies to consider the international, economic, social, political, and legal implications of space research and exploration. Toward this end, NASA has negotiated several contracts with private research organizations to study these implications. The committee has also called upon a legal foundation for an analysis of all available space law literature and proposals for the control and administration of outer space activities.

CHAPTER 2

NASA HIGHLIGHTS¹ (OCTOBER 1, 1959—MARCH 31, 1960)

1959

October 4

A Little Joe launch vehicle carrying a boilerplate Mercury capsule with a test escape system was launched from Wallops Station. Test objectives were to determine whether the vehicle-capsule-escape system was operational and to check the vehicle's "destruct" system. Both objectives were met.

October 13

Explorer VII was launched into orbit by a Juno II. Data from the satellite have provided new information on fluctuations of the Van Allen radiation zones as much as 500 miles at a time and radiation intensity variations as much as 10 times in several hours. Substantial evidence has been shown of interrelationship between periods of solar activity, changes in cosmic ray intensities, ionospheric disturbances, and geomagnetic storms above the Earth.

October 21

The President announced plans to transfer the Army Ballistic Missile Agency's Development Operations Division, Huntsville, Ala., to NASA. The President vested responsibility in NASA for the superbooster program, including Project Saturn, the 1.5-million-pound-thrust cluster of eight rocket engines of the Jupiter type.

October 28

NASA launched a 100-foot-diameter inflatable sphere of microthin, aluminized polymer plastic from Wallops Station in a suborbital test. The experiment, a preliminary to communications satellite development, tested ejection and inflation of the sphere and operation of the X-248 rocket which will be the third stage of the Delta vehicle. The sphere reached a 265-mile altitude and traveled 500 miles over the Atlantic Ocean.

November 4

A second Little Joe was launched at Wallops Station to test the escape system under severe dynamic pressure. The launch vehicle performed well, but the escape rocket ignited several seconds too late and desired dynamic pressures were not achieved.

November 18

A two-stage rocket carrying a sodium vapor payload was launched from Wallops Station to an altitude of 150 miles. Its sodium vapor trail was visible for hundreds of miles along the Atlantic seaboard, and indicated wind directions and characteristics at high altitudes. Similar experiments on November 19 and 20 failed to produce sodium vapor trails.

¹ Details are in later chapters.

November 18

A memorandum of understanding for operation of Project Saturn, pending formal transfer to NASA, was endorsed by NASA and DOD. The agreement provided for technical direction of Saturn by the NASA Administrator, with advice and assistance of a committee composed of NASA and DOD representatives.

November 26

An attempt to launch a lunar satellite failed when the plastic shroud protecting the sensitive payload of the satellite separated prematurely.

December 4

A third Little Joe carried a rhesus monkey, in a dual-purpose mission to test operation of the escape system and to obtain measurements of biological responses of a primate to space flight. All objectives of the test were met.

December 7

NASA offered the services of its tracking stations—subject to consent of the host countries—to the Soviet Union for its manned space flight program. NASA also offered to provide equipment or use equipment furnished by Soviet scientists, if special recording or data reduction facilities should be required.

December 11

The Vega launch vehicle development program was canceled in favor of an Agena B program, using Atlas-Agena B and Thor-Agena B vehicles, to avoid duplication and to increase reliability by keeping the number of rocket vehicles in the program to a minimum.

December 22

The first Javelin sounding rocket was launched from Wallops Island, in a joint United States-Canadian experiment. The chief objective—to measure the intensity of galactic radio noise—was not reached because of payload failure. However, the payload was carried to an altitude of 650 miles by the four-stage Javelin.

*1960**January 1*

NASA headquarters was reorganized. Office of Launch Vehicle Programs was established; several other offices were redesignated.

January 8-16

NASA gave extensive support to the National Academy of Sciences delegation to the first International Space Science Symposium, Nice, France. The symposium was sponsored by the International Committee on Space Research (COSPAR).

January 16

As a preliminary experiment in Project Echo, a communication satellite, a 100-foot-diameter inflatable sphere was launched on a suborbital trajectory. Although it ruptured on inflation, voice and radio signals were transmitted to the sphere and bounced or reflected back to ground stations.

January 21

The Project Mercury capsule escape system was tested at high dynamic pressure during a Little Joe flight. (Atmosphere entry was not involved in this test.) Sequencing of parachutes and the recovery operation were satisfactory. A rhesus monkey rode inside the capsule in a biopack, sustaining stresses as high as 20g without ill effects.

January 26

The second joint United States-Canadian Javelin sounding rocket experiment was launched from Wallops Island. The launch vehicle performed as programed, but the payload malfunctioned.

January 29

The Office for United Nations Conference was established to carry out NASA's responsibility for planning, coordinating, and directing United States participation in the First International Conference on the Peaceful Uses of Outer Space. Dr. John P. Hagen was named director of the new Office.

February 9

X-15 research airplane No. 1 was delivered by the contractor, North American Aviation, Inc., to NASA for further testing.

February 26

An agreement was reached for establishment of Project Mercury tracking networks in Australia.

February 27

A third 100-foot-diameter inflatable sphere was launched in a ballistic trajectory from Wallops Island. The sphere again ruptured, but voice transmissions were relayed from Bell Telephone Laboratories, Holmdel, N.J., to General Electric's Schenectady laboratories and to MIT's facilities at Round Hill, Mass.

March 1

The Office of Life Sciences was established in NASA headquarters to plan, organize, and operate a program of research dealing with (1) survival and performance of man in space; (2) the effect of the space environment on biological organisms, systems, and processes; and (3) the search for extraterrestrial life forms. Dr. Clark T. Randt was named director of the new Office.

March 10

The Office of Reliability and Systems Analysis was established in NASA headquarters, to direct a program designed to evaluate and improve operational reliability of NASA launch vehicles and payloads. Landis S. Gephardt was appointed director.

March 11

Pioneer V, a 94.8-pound space probe, was launched on a trajectory which carried it into a solar orbit. As the period ended, the probe was transmitting scientific data from a distance of nearly 3 million miles from earth.

March 15

The President redesignated NASA facilities at Redstone Arsenal, Huntsville, Ala., as the George C. Marshall Space Flight Center.

March 19

An agreement was reached for a Project Mercury tracking station in the Canary Islands.

March 23

NASA test pilot Joseph Walker made the first familiarization flight with X-15 No. 1. All previous test flights had been performed by the contractor, North American Aviation, Inc.

March 25

NASA announced the selection of Aerojet-General Corp., a subsidiary of General Tire & Rubber Co., to build the power conversion equipment for the SNAP-8 (system for nuclear auxiliary power) reactor, and to integrate the reactor into an operational system.

March 28

Two clustered first-stage engines for the Saturn vehicle were static tested. Performance was good, and noise levels were found to be somewhat lower than had been anticipated.

April 1

The fourth suborbital test launch of 100-foot-diameter inflatable sphere operated as programmed. Launched by a two-stage vehicle from Wallops Island, it reached an altitude of 200 miles, and a 12-sentence taped voice message was relayed via the sphere from Holmdel, N.J., to Round Hill, Mass.

April 1

The first production model Project Mercury capsule was delivered to NASA by the contractor, McDonnell Aircraft Corp., St. Louis, Mo. The capsule is instrumented for an escape system and recovery system test to be conducted by NASA's Space Task Group and McDonnell.

April 1

TIROS I, the first of a series of experimental meteorological satellites, was launched into orbit. Its performance far exceeded expectations as its narrow- and wide-angle cameras transmitted thousands of clear photographs of the earth's cloud cover, providing significant data on the formation and extent of clouds.

CHAPTER 3

EXPERIMENTAL MISSIONS

MAJOR EXPERIMENTS

Three major experiments—the Explorer VII and TIROS I satellites and the Pioneer V deep space probe—transmitted scientific information of great significance.

Data from Explorer VII have indicated possible relationships between solar events and geomagnetic storms. Pioneer V has been steadily transmitting radiation data and other scientific information from deep space in the solar system—millions of miles from earth. And TIROS I, forerunner of operational weather satellites to come, has transmitted thousands of clear photographs of the earth's cloud cover.

The three experiments are refinements and improvements of earlier experiments and represent the Nation's step-by-step progress into space.

EXPLORER VII² MEASURES EARTH'S RADIATION

Explorer VII, a 91.5-pound radiation-probing satellite originally planned for the International Geophysical Year, was launched on October 13 at 11:31 a.m. eastern daylight time by a Juno II.³ When launched, the satellite was set spinning at 450 revolutions per minute to stabilize it. Explorer VII attained an elliptical orbit with a perigee of 344 miles and an apogee of 678 miles. Its life is estimated at about 20 years.

Contains seven experiments

The satellite, 30 inches in diameter and 30 inches long, consists of two truncated cones joined at their bases. Preliminary analyses of the data transmitted from its seven experiments have been encouraging. The experiments are as follows:

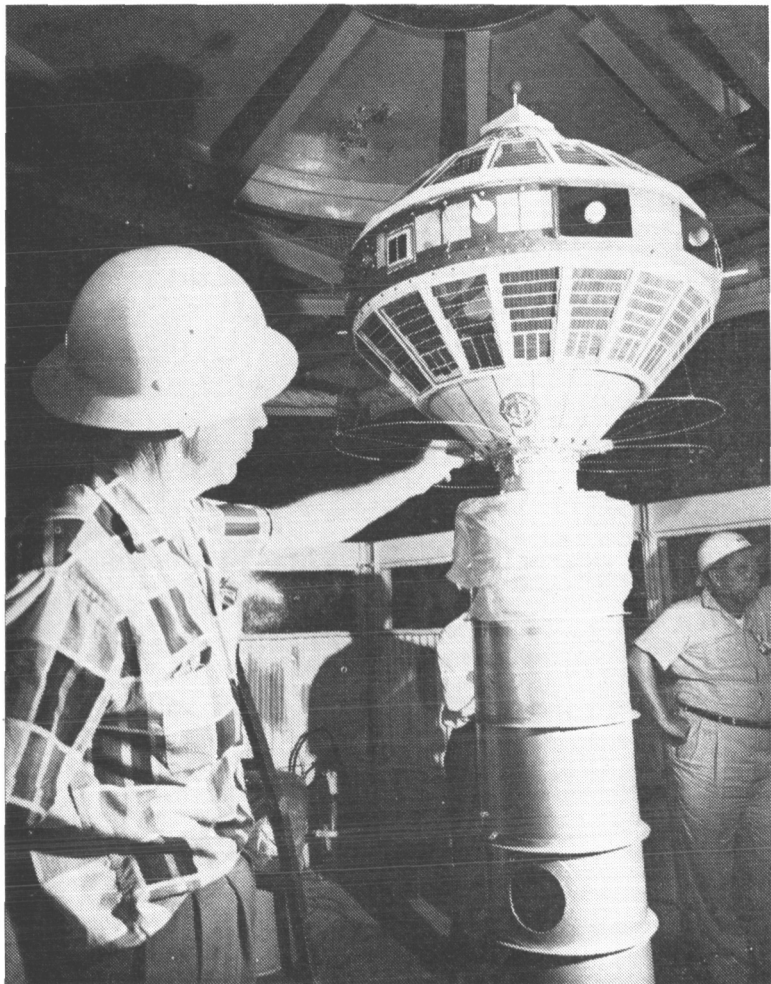
(1) Radiation balance experiment: To measure the thermal radiation balance, or "heat budget" of the earth.

It is known that the earth receives more energy from the sun in the equatorial zone than it radiates into space and that it radiates more energy from the polar regions than it receives from the sun. This means that heat energy must be transferred from the equatorial to the polar regions by means of ocean currents and the atmosphere. The transfer of heat is studied in this experiment by measuring: (1) the direct radiation falling on the "top" of the earth's atmosphere from the sun; (2) the fraction of this radiation that is reflected by the earth, clouds, and atmosphere; and (3) the fraction of radiation that is absorbed by the earth and eventually reradiated back to space.

² Also called "1959 Tota," carrying on the scientific designations originally established for the International Geophysical Year (IGY).

³ All launchings were from the Atlantic Missile Range (AMR), Cape Canaveral, Fla., unless otherwise noted.

Six sensing elements are used to determine the different quantities needed for the above measurements. The sensors are 3.25 centimeters in diameter, hollow, hemispherical shells of thin sheet silver. Two of the hemispheres are coated black and are equally sensitive to both solar and terrestrial radiations. Another, painted white, is more sensitive to terrestrial radiation than to direct and reflected solar



The Explorer VII satellite, attached to the fourth stage of the Juno II vehicle, is inspected prior to launching October 13, 1959.

radiation. Another, with a polished gold surface, is more sensitive to direct and reflected solar radiation than to terrestrial radiation. A black spherical sensor mounted on top of the satellite, and a sunshaded hemispherical sensor on the equator of the satellite, complete the assembly of sensors necessary for these measurements.

The temperature of each sensor is dependent upon the amount of radiation present to which it is particularly sensitive. These tem-

peratures are telemetered to data-receiving stations on earth. The calculation of the earth's "heat budget" from the data is a long and tedious process when done by hand—therefore, a computer method of reducing the data is being developed.

(2) Lyman-Alpha and X-ray experiment: Designed to measure some of the long-wave portions of the spectrum of the sun's radiations—solar ultraviolet and X-ray intensities and their variations, especially during solar flares.

Solar ultraviolet (Lyman-Alpha) radiation is being measured with two photosensitive ionization chambers, cylindrical in shape, $\frac{3}{4}$ -inch in diameter and $1\frac{1}{4}$ inches long. A combination of lithium fluoride windows and a filling of nitric oxide gas sensitizes the counters to the portion of the ultraviolet spectrum in which Lyman-Alpha radiation is the main constituent. The X-ray ionization chambers, similar in size and shape to the Lyman-Alpha chambers, are filled with argon gas and have beryllium windows.

A photocell sensor is used with the solar ultraviolet and X-ray equipment, to determine the satellite's position with respect to the sun.

(3) Heavy primary cosmic ray experiment: Designed to determine the flux, or intensity, of heavy primary cosmic rays. It employs an ionization chamber filled with argon gas.

(4) Cosmic ray experiment: Two Geiger-Mueller counters, designed to measure cosmic radiation and the less energetic particles in the lower fringes of the Van Allen radiation zone and the regions just below the zone. One counter is unshielded; the other has a lead shield about 1 millimeter thick.

(5) Exposed solar cell experiment: To determine the performance of an unprotected solar cell in the space environment. The effect of erosion upon a silicon cell mounted on the satellite is indicated by the variation of the voltage developed by the cell during exposure to light.

(6) Micrometeoroid experiment: To measure micrometeoroids of more than 10 microns diameter by means of a cadmium sulphite photoconductor covered by an optically opaque film. Micrometeoroids striking the film will let sunlight into the cell, thus registering impacts, which are telemetered to earth.

(7) Temperature experiment: To measure temperature on the satellite surface; consists of a solar cell cluster, a battery pack, and one Geiger-Mueller counter.

Data were being radioed to earth by two transmitters. One, operating on 108 megacycle and powered by nickel-cadmium batteries, was used principally for tracking and micrometeoroid data. Its batteries went dead on December 5. At the end of the reporting period, the other transmitter, powered by solar cells, was still transmitting data on 19.9915 megacycles. An automatic timing device will cut off the solar-powered transmitter one year after launching to to release the radio frequency for other uses.

Preliminary results

On December 30 scientists associated with the Explorer VII experiments reported preliminary findings. Here are brief excerpts and condensations of their statements:

Verner E. Suomi, professor of meteorology and soils, University of Wisconsin, said of the radiation balance experiment:

While the satellite is not designed to look at details in the weather below, it does indicate clouds or storm areas about a thousand miles across. This shows up readily on the sunlit portion of the earth because of the large amount of reflected sunlight (picked up by the sensors). However, it is also possible to relate the changes in long-wave radiation on the dark side of the earth to positions where cold or warm air exists.

If this comparatively crude experiment can do this, more sophisticated satellites now being planned and under construction can recognize storm systems even on the dark side of the earth.

Noting the variations in the amount of heat radiated by the earth over a small area of the United States, Dr. Suomi said it is possible to relate them in the satellite record with the weather map for the area but—

at this stage I am not very confident because the key to it is to go in the reverse direction—to take the variations measured by the satellite and say there are things below. At the present time we are just finding these relationships; we really need to have much more data and increase the confidence in them * * *.

HEAVY PRIMARY COSMIC RAY RESULTS

Martin A. Pomerantz, director of the Barton Research Foundation of Franklin Institute, Swarthmore, Pa., discussed the heavy primary cosmic ray experiment. He said that heavy primary cosmic rays—

consist of heavy atoms stripped of external electrons and endowed with very high energies. They come from the far reaches of our galaxy and have traveled vast distances through interstellar space before reaching us. We can learn much of fundamental interest by studying their characteristics. The fact that they have survived their long journey yields information about conditions in cosmic space * * *.

The data record is accomplished by monitoring the rate of [the particles'] arrival at fixed locations over extended periods of time * * *. The detector employed is the so-called "pulse ionization chamber" and it enables us to select the heavy primary cosmic rays, even in the presence of much larger background of radiation of other types.

This is the first occasion in which this sort of detector has been used in a satellite experiment. It has proved especially well adapted to this application because it combines a high sensitivity and a great capability for discriminating against interfering effects.

Fluctuations in intensity, probably associated with storms in the sun, have been observed but have not yet been studied in any detail * * *. In particular, we shall be especially interested in seeking to detect any heavy nuclei emitted directly by the sun—an occurrence known to transpire in the case of hydrogen * * *.

LOW ENERGY PARTICLES EXPERIMENT

Brian O'Brien, an associate of James A. Van Allen of the State University of Iowa, discussed the cosmic ray and low energy particles experiment. Speaking of the short-term effects of radiation bursts upon the Van Allen radiation belt, he said:

* * * On several occasions the apparatus has detected what appears to be bursts of sporadic radiation near the inner edge of the outer radiation belt. These bursts may be related to the bursts of X-rays which are observed at balloon altitudes, but at present we can only say that the cause is unknown or uncertain.

Another thing we have found from a study of the sequence of passes over North America from the 16th of October (1959) through to the 20th was an effect which apparently is related to a geomagnetic storm which began on the 18th of Oc-

¹ The heavy nuclei are of special interest because their origins, and their relationships to the fundamental processes going on in the sun and stars, are not yet fully known. Moreover, the heavy nuclei are the most ionizing of the cosmic ray particles, hence have a greater effect on living substances; for this reason they are of practical interest to the people concerned with manned space flight.

tober. On the 18th of October only, the counters measured radiation which appears to have been generated * * * 13,000 miles out from the center of the earth * * * between the two radiation belts. This phenomenon is being compared with results from Explorer IV, in which geomagnetic storms during 1958 were being studied.

The third phenomenon I want to mention is associated with what we call the Forbush phenomena. On occasions over the years, people with cosmic ray detectors on the ground have observed a sudden decrease in cosmic ray intensity, generally of a few percent; this covers a period of several days. Quite often, this Forbush decrease is associated with geomagnetic storms * * *.

He pointed out that sea level detectors record only very high energy cosmic rays. Balloon studies at high altitudes have revealed that the Forbush decrease is much stronger for lower energy particles observed at sea level.

Now, with Explorer VII [said Professor O'Brien] we can study even lower energy particles. We studied one sequence using data provided by Dr. Hugh Carmichael in Canada. He has sea level measurements and he has found for one particular Forbush decrease a 9-percent change in his counting rate over a period of many days, whereas Explorer VII has found something like a two to three hundred percent change. * * *

Professor O'Brien said that since these decreases are associated with geomagnetic storms, it is possible that Explorer VII findings will throw further light on the nature and mechanism of geomagnetic storms and their effect on radio communications.

MICROMETEOROID EXPERIMENT

Herman E. La Gow, head of the Planetary Atmospheres Branch of NASA's Goddard Space Flight Center, reported on the status of the micrometeoroid and erosion experiments. Said Mr. La Gow:

This experiment is conducted to evaluate some of the hazards in the space environment. It consists of three evaporated cadmium sulfide conductors which are covered with thin but optically opaque films. The erosion of these surfaces by either high velocity molecules or impacts from micrometeorites would produce openings in the covers. The admitted sunlight would change the electrical resistance in the cell in proportion to the area of the hole.

Analyses of the telemetered records to date are incomplete * * * [but] approximately one-half of 1 percent of the total area of one cell was admitting sunlight. This puncture occurred during the launch phase and hence is not from a micrometeorite. No further penetration or erosions have been noted to date. The telemetry equipment in the cell and the sensor to measure the temperature of one of the cells have functioned properly. * * *

SATELLITE TEMPERATURE EXPERIMENT

Gerhard Heller of the Research Projects Laboratory, Army Ballistic Missile Agency (now the Research Projects Division, Marshall Space Flight Center), Huntsville, Ala., reported that the temperature within the satellite had been staying within its design limits of 32° F. to 140° F. Data from the Lyman-Alpha and X-ray experiment were still being analyzed as the report period ended. The equipment for this experiment has been working properly; however, the satellite is in the radiation belt for such long periods that the instruments are saturated by the radiation. As a consequence, the instruments are unable to indicate the solar radiations that they were designed to observe. Instead, the equipment gives a good indication of the structure of the lower edge of the radiation belt. This is provided by the change from saturated condition to unsaturated condition as the

equipment comes out of the radiation belt and again as it is carried back into the radiation belt.

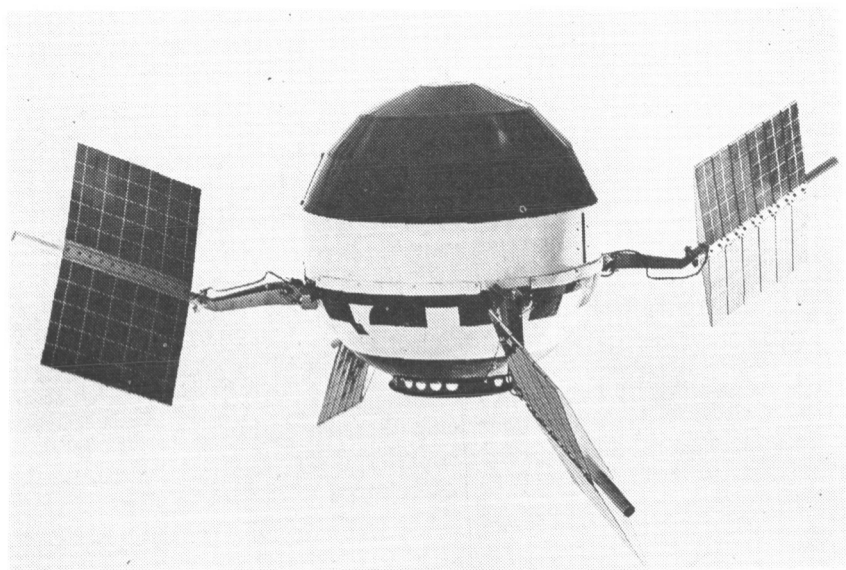
PIONEER V⁵ ORBITS THE SUN

Space probe launched by Thor-Able

Pioneer V is a 94.8-pound probe designed to gather scientific data from deep space and to test communications over interplanetary distances. On March 11, at 8 a.m., eastern standard time, a Thor-Able fired the probe on a trajectory that carried it into a solar orbit.

United Kingdom facility triggers separation

The Thor-Able launched Pioneer V as planned and at 8:27 a.m. eastern standard time the radio telescope facility at Jodrell Bank, near Manchester, England, transmitted the signal which triggered separation of the probe from the third stage.



Pioneer V with solar-cell vanes extended.

Transmitter sends data

Since then, Pioneer V's 5 watt radio transmitter has been steadily sending data on radiation and other phenomena from deep space, millions of miles from earth.⁶ When the probe is 5 to 6 million miles from earth, a far more powerful transmitter-receiver (150 watts) will be turned on, which should permit radio contact to 50 million miles from earth.⁷

Data being analyzed

On April 1, data were still undergoing preliminary analysis; at midnight on that date, the probe was 2,977,515 miles from earth. The

⁵ IGY designation, "1960 Alpha."

⁶ The probe far exceeded the previous communications record distance of 407,000 miles set by Pioneer IV.

⁷ The 150-watt transmitter was activated at 5:04 a.m., eastern daylight time, on May 8, but 2 weeks later, battery deterioration necessitated a switch back to the 5-watt transmitter

5-watt transmitter-receiver was still working strongly, demonstrating that we can communicate over interplanetary distances.

Orbital cycle: 312 days

The probe will circle the sun in 312 days, reaching its perihelion (point closest to the sun) of 74,967,000 miles on August 10, 1960, and an aphelion (farthest distance from the sun) of 92,358,000 miles on January 13, 1961. Each circuit will total 514,500,000 miles.

Four experiments aboard

Besides the two radio transmitters, the probe contains—

(1) A high-energy radiation counter to measure radiation streaming from the sun; it consists of six argon-filled cylinders ranged around a seventh.

(2) A total radiation flux counter to measure spatial distribution of energetic particles and medium-energy electrons and protons; it consists of a gas filled ion chamber and a Geiger-Mueller tube.

(3) A micrometeoroid counter to record the number and the density of meteoric dust particles striking the probe; it consists of a diaphragm mounted on the probe's surface and a microphone.

(4) A magnetometer to measure the strength of magnetic fields and to determine their orientation in space.

Solar vanes recharge batteries

Pioneer V carried numerous associated experiments and instrumentation. Four paddle-shaped, 14- by 18-inch vanes jut from the globe-shaped payload. Each vane is studded with 1,200 solar cells, which provide power to recharge the probe's nickel-cadmium batteries.

Pioneer V sets record

At 7:30 p.m., eastern standard time, on March 13, Pioneer V broke the long distance communications record—407,000 miles—established by Pioneer IV. At 2 a.m., eastern standard time, on March 18, its 5-watt transmitter sent data from 1 million miles in space, on command from the tracking station at Kaena Point, Hawaii. At that reception, the data consisted of two separate cosmic ray counts; a record of 87 micrometeoroid impacts; temperature inside the probe (68°F); temperature on the probe's surface (27°F); and various magnetometer measurements.

Launched counter to earth rotation

Pioneer V was launched to a velocity of 24,886 miles per hour—575 miles per hour faster than the minimum speed required to overcome the earth's gravitational pull. As the sphere sped on its course, earth's gravity at first had a powerful effect. By midafternoon of the first day's flight, the speed relative to the earth had slackened to less than 8,000 miles per hour.

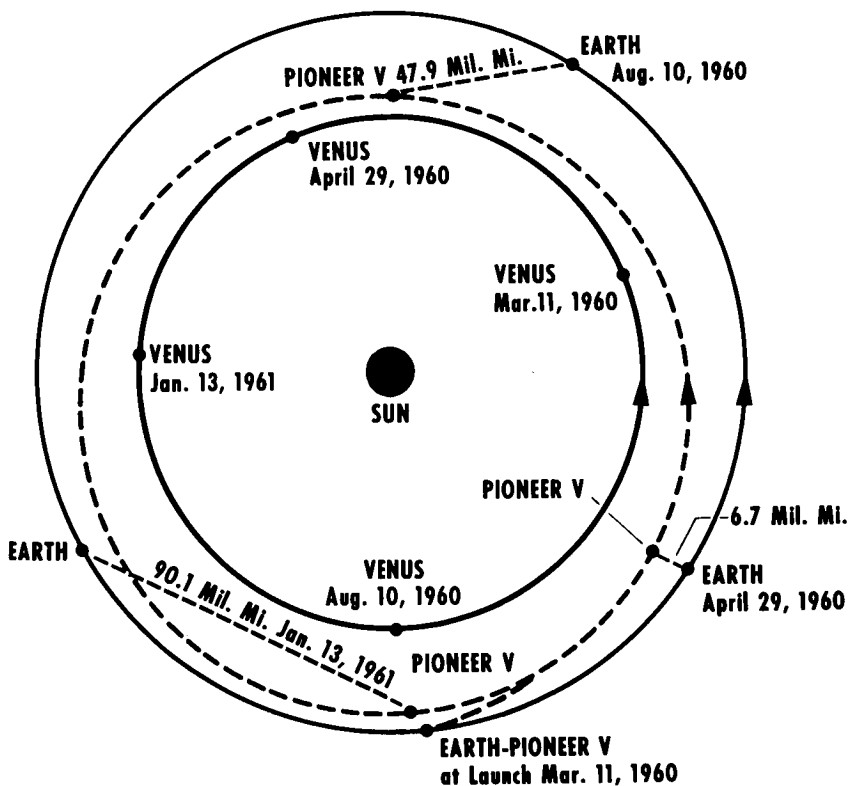
To achieve the desired orbit—perihelion close to the Sun and near the orbit of Venus—Pioneer V was launched in a direction opposite to that of the earth's revolution around the sun. With a speed less than earth's—and hence with a reduced centrifugal force to offset the sun's gravitational pull—the probe would start falling inward toward the sun. (Previous probes had been launched so that their

speed was added to that of the earth, and they thus moved outward, away from the Sun.)

Probe will become artificial planetoid

As the probe is pulled into the sun's gravitational field and becomes the third manmade planetoid, its speed will increase to an estimated average orbital velocity of 67,750 miles per hour. In comparison, earth's orbital velocity is 66,593 miles per hour; that of Venus, 78,403 miles per hour.

PATH OF PIONEER V



Projected orbit of the Pioneer V planetoid and the orbits of Earth and Venus.

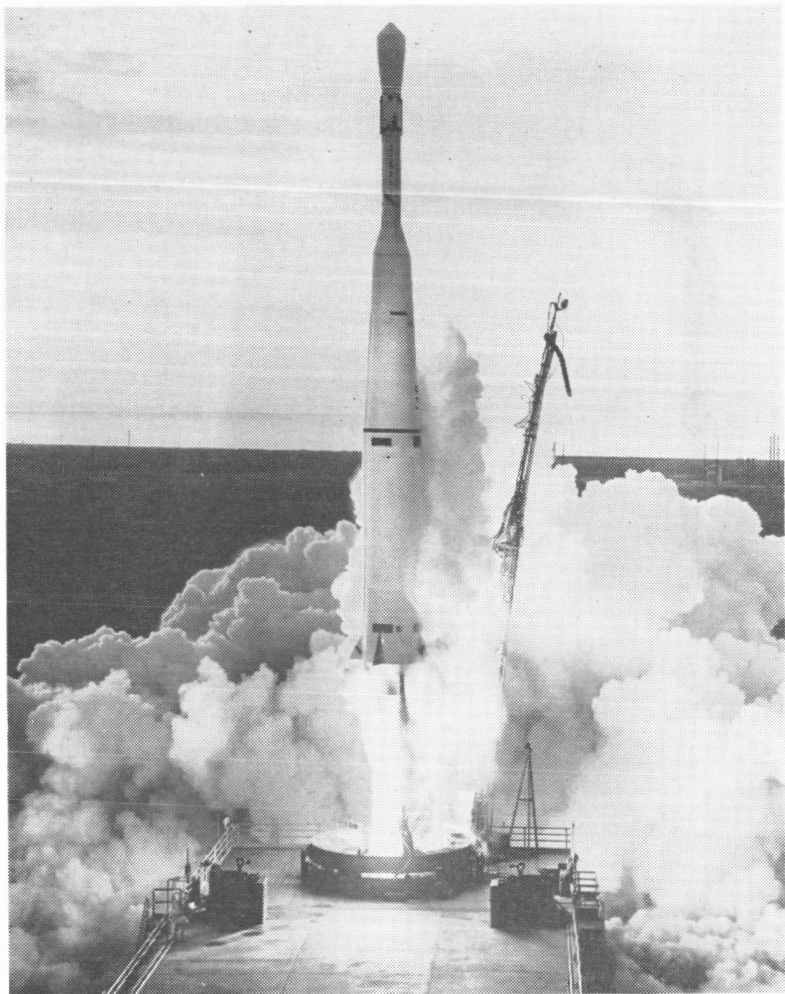
Expect 5-month radio contact

When the probe reaches perihelion it will be 46,400,000 miles from Earth, hence still theoretically within range of the 150-watt transmitter.

Periodic radio contact will be attempted with Pioneer V for the 5 months until it moves out of range. If the probe survives the stresses of space travel, radio contact will be established again in 1963 when it swings back to within 50 million miles of the earth.

TIROS I⁸ LAUNCHED*Attains nearly circular orbit*

TIROS I (Television Infra-Red Observation Satellite), an experimental weather satellite, equipped to take photographs of the earth's cloud cover, was launched at 6:40 a.m., eastern standard time, on April 1, 1960. The project is a joint NASA-U.S. Weather Bureau undertaking.



Thor-Able rocket, carrying TIROS I, is launched from AMR, Cape Canaveral, Fla.

A Thor-Able launched the 270-pound satellite into the planned, nearly circular orbit: apogee, or greatest distance from the earth, 465 miles; perigee, lowest point of orbit, 430 miles; time required to complete one circuit (orbital period), 99.19 minutes. By 8:20 a.m.,

⁸ IGY designation, "1960 Beta."

TIROS' two television cameras had already begun transmitting pictures of cloud patterns.

Cameras sweep the earth

TIROS' cameras are sweeping a band of the earth's surface between 50 degrees north and south latitudes; the area covered extends roughly from Montreal, Canada, to Santa Cruz, Argentina; from Le Havre, France, to southern Africa; and from northern Manchuria to New Zealand. One camera can photograph hundreds of thousands of square miles, the area varying with the angle of the lens with respect to the earth. The other instrument, a "high-resolution" camera capable of 10 times more detail, can photograph an area 80 miles on a side within the territory photographed by the wide-angle camera; it reproduces the structure and texture of clouds within the overall cloud mass.

Since the satellite is space-oriented, the lens points earthward only part of the time. Photographs of the earth's cloud cover may be taken only when a sunlit portion of the earth comes within the camera's view.

Satellite transmits hundreds of photographs

During its first few days in orbit, TIROS relayed hundreds of photographs of a quality surpassing all expectations. Francis W. Reichelderfer, chief of the U.S. Weather Bureau, said that—

* * * initial results from this one experimental satellite lead us to believe that a new era in meteorological observing is about to open for us.

On April 2, the satellite transmitted pictures of a 1,500-mile-diameter storm, the edge of which was 300 miles off the coast of Ireland. Within the storm's boundaries were circular bands of clouds 20 to 100 miles across. (The evening of the same day, the clock-timer commanding the data-storage tape recorder for the high-resolution camera malfunctioned. Since then, photographs from that camera have been received only by direct transmission.⁹ During the predicted 1,300 revolutions of its useful operational life (about 3 months) TIROS I will pass over a major portion of the earth's inhabited land areas.

First event in 10-year plan

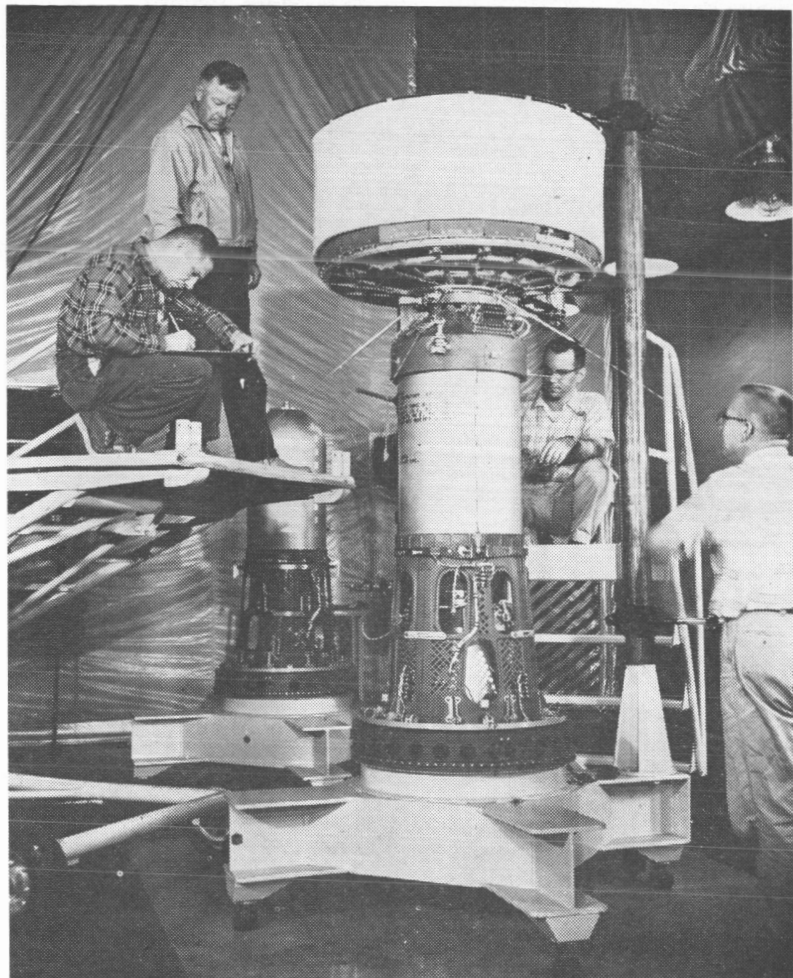
The launching of TIROS I led off NASA's list of specific mission target dates for 1960 in its 10-year plan. Several satellites of similar type will follow. These will be succeeded by the more advanced, earth oriented Nimbus series of satellites.

Details of launch

The Thor-Able vehicle—90 feet long, 8 feet in diameter—consisted of three stages: (1) Thor (150,000 pounds thrust); (2) Liquid-propellant Able rocket (7,500 pounds thrust) adapted from Vanguard, equipped with a special Bell Telephone Laboratories' guidance system to correct by radio command, deviations from the planned trajectory; (3) Hercules-Allegany Ballistics Laboratory solid-propellant rocket (3,000 pounds thrust) equipped with a special radio beacon designed by the Lincoln Laboratory of Massachusetts Institute of Technology for radar tracking.

⁹ On May 10, the clock-timer began functioning again.

Following separation from the second stage, the third stage coasted for $6\frac{1}{2}$ minutes after engine shutoff and before ignition. During this period it was stabilized on its course by spinning at 90 revolutions per minute. The satellite payload separated from the third stage 25 minutes after burnout.



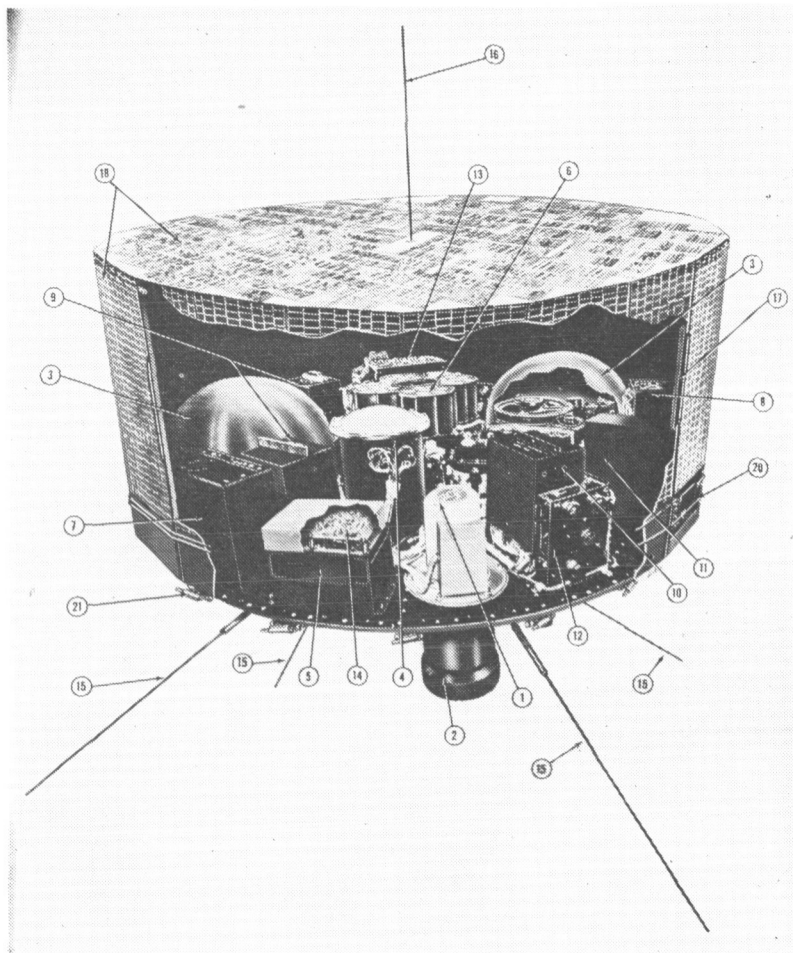
TIROS I, experimental meteorological satellite, is inspected by RCA personnel. It is attached to the third stage of the Thor-Able booster which fired it into orbit, April 1, 1960.

TIROS has 9,200 solar cells

TIROS I is a drum-shaped structure of aluminum and stainless steel, 42 inches in diameter and 19 inches thick. Three pairs of spin rockets encircle its baseplate; a "turnstile" transmitting-antenna extends below it, and a receiving antenna projects above. Almost the entire outer surface of the satellite is studded with 9,200 solar cells, which convert heat from the sun into electrical power by charging nickel-cadmium batteries.

Ground station activities

The satellite's program is prepared at NASA's Goddard Space Flight Center. Instructions are then sent to the two ground stations—Fort Monmouth and the Lockheed Missile and Space Division's facility at Kaena Point, Hawaii—which instruct the satellite. Backup stations at Cape Canaveral, Fla., and Princeton, N.J., also receive TIROS' signals, but cannot transmit commands. Data received at all stations is eventually fed back to Goddard.



Instrumentation of the TIROS I meteorological satellite: (1) One of the two $\frac{1}{2}$ -inch Vidicon TV cameras; (2) wide-angle camera lens; (3) tape recorders; (4) electronic timer for operational sequencing; (5) TV transmitter; (6) chemical batteries; (7) camera electronics; (8) tape recorder electronics; (9) control circuits; (10) auxiliary controls; (11) power converter for tape motor; (12) voltage regulator; (13) battery charging regulator; (14) auxiliary synchronizing generator for TV; (15) transmitting antennas; (16) receiving antenna; (17) solar sensor to measure position of satellite with respect to sun; (18) solar cells; (19) spin-up rockets; (20) de-spin mechanism.

Recording techniques

Connected to each camera is a magnetic recorder that can store as many as 32 photographs, taken at 10- to 30-second intervals while the satellite is out of range of ground stations. The recording tape, made of Mylar plastic, is on a 400-foot loop, which is pulled at 50 inches per second during recording or playback. Pictures stored on the tape can be relayed to the ground receivers in a 3½-minute period. The tape is then erased and the next series of pictures is recorded.

Storage and transmitting

Upon radio command, the cameras can bypass the recording system and transmit pictures directly to the nearest ground station; each of these stations is in the satellite's range about 12 minutes, or less, per pass. Each camera has a ½-inch "Vidicon" tube—a device that stores images received when the shutter opens. An electronic beam converts the stored picture into an electronic signal transmitted, to receivers on earth by twin 2-watt FM transmitters operating at 235 megacycles.

Transmitted data are displayed immediately on ground-station television screens, by the kinescope process, photographed, and taped. The satellite contains two 30-megawatt beacon transmitters operating on 108 megacycles and one 108.03-megacycle beacon for tracking and relaying data on attitude (orientation), equipment operation, and space environment.

Spin rate is controlled

To prevent precession, or wobbling, TIROS I must rotate no slower than 9 revolutions per minute; for clear photography it must rotate no faster than 12 revolutions per minute. When the satellite separated from the third stage, it was spinning at a much faster rate—about 90 revolutions per minute. A de-spin mechanism—weighted wires wrapped around the main structure before launch—unwound on schedule and was thrown off into space, slowing rotation to 10 revolutions per minute. An infrared scanner shows how fast the satellite is spinning and indicates its orientation to the horizon when photographs are being taken.

LUNAR SATELLITE ATTEMPT

On November 26 an attempt to launch a 372-pound paddlewheel spheroid into a lunar orbit, failed because of premature separation of the payload's protective plastic shroud. The payload contained equipment that was to have transmitted photographs of the moon's hidden side, and devices to gather data on micrometeoroids, magnetic fields, cosmic rays, and radio waves.

The payload was launched at 2:26 a.m., eastern standard time. Forty-five seconds later, a burning fragment dropped from the launch vehicle and radio contact was lost. At 104 seconds after liftoff, all telemetry stopped. The premature shroud separation was caused by internal pressures that built up as a result of apparently inadequate venting.

RADIATION SATELLITE ATTEMPT

An attempt to launch a 22.8-pound radiation satellite at 8:35 a.m., eastern standard time, on March 23 ended when the Juno II launch vehicle was unable to lift the payload to orbital velocity. A malfunction apparently occurred in the cluster of solid-propellant rockets forming the upper stages; causes are under study.

The satellite was equipped to record detailed data within the Van Allen radiation region for an extended period of time.

AEROBEE 150-A'S LAUNCHED FROM WALLOPS

On February 16, the first Aerobee 150-A sounding rocket—a new type in the Aerobee series, stabilized with four fins instead of the usual three—was fired from the recently completed launch tower at Wallops Station. A malfunction in the thrust chamber caused the rocket to fail after it rose to an altitude of about 3 miles. A second Aerobee 150-A, launched on March 25, reached an altitude of 150 miles and met most of its objectives, which included testing instrumentation to measure rocket performance—resistance to vibration, etc.—and to count micrometeoroid impacts.

X-248 ENGINE FLIGHT TESTED IN JAVELIN

On January 26, a solid-fuel Javelin sounding rocket—employing the X-248 engine (developed in the Vanguard program) as a fourth stage—was fired from Wallops Station to an altitude of 600 miles. Performance data were telemetered on the X-248, which is being readied for use as the third stage in the Delta vehicle under development by NASA. The telemetered information included data on vibration, acceleration and afterburning—that is, irregular burning within the rocket engine after main burning and thrust have ceased. When this occurs, the stage spurts ahead and sometimes bumps into the next stage or separated payload.

Antenna ejection system fails

The Javelin carried an experiment prepared by the Defense Research Telecommunications Establishment of Canada to measure galactic radio noise. As was the case in an earlier experiment with the Javelin on December 22, 1959, the payload's antenna ejection system failed.

NIKE-ASPS LAUNCHED

In two launchings (Mar. 1 and Mar. 4), malfunctions in the nose cone ejector system of Nike-Asp sounding rockets caused failure of experiments intended to measure ultraviolet radiation from the sun. On both occasions telemetry and other systems worked as planned, and the rockets reached altitudes of 150 miles.

SODIUM FLARE EXPERIMENTS LAUNCHED

NASA launched three sodium-flare rocket experiments as part of the U.S. contribution to International Rocket Week, November 15-21, 1959. One yielded important information about upper atmosphere wind velocity and direction; two firings, November 19 and 20, failed to produce sodium trails.

Reveals strong windshear effects

The successful firing was made at 5:17 p.m. eastern standard time, November 18, from Wallops Station, Va. The vehicle, consisting of a Nike first stage and an Asp second stage, began to emit sodium vapor at a 50-mile altitude and continued the emission until it reached 150 miles. The glowing orange-yellow cloud was visible for about 15 minutes over a large section of the Atlantic seaboard. Observation of the cloud revealed powerful windshear effects (that is, several layers of strong winds moving at different velocities at altitudes of 70 to 100 miles).

Experiment employs optical tracking

Data from the behavior of the sodium vapor cloud were obtained by special NASA optical tracking stations temporarily located at Cherry Point, N.C.; Bowling Green, Va.; Andrews Air Force Base, Md.; Dover, Del.; and Wallops Station.

TABLE 1.—*NASA satellites, lunar probes, and space probes, Oct. 1, 1959–Apr. 1, 1960*
[Official statistics prepared by the National Aeronautics and Space Administration]

Name, by type, orbit weight, payload weight	Lifetime	Launching vehicle	Payload instrumentation	Test results	Perigee (miles)	Apogee (miles)
Explorer VII (1959 Iota) U.S. satellite (2 truncated cones joined at base). Scientific payload and total weight in orbit: 91.5 pounds.	Oct. 13, 1959–20 years	Modified Juno II	Dimensions: 30 inches in diameter, 30 inches long. Experiments: Radiation balance; Lyman-Alpha X-ray; heavy primary cosmic ray; cosmic ray; micro-meteoroid; exposed solar cell; temperature measurements. Shell composition: Fiberglass and sand-blasted aluminum foil. Antennas: 20 mc. turnstile antenna consists of 4 flexible quarter wavelength elements which are unreelable in the plane of the satellite equator from a motor-driven drum on the spin-axis; 108 mc. is a turnstile antenna with 4 rod elements. Transmitters: (a) 108 mc. at 12 mw., (b) 20 mc. at 600 mw. The 2d and 3d harmonics at 40 and 60 mw. were fed to the antennas at 15 mw. and 5 mw., respectively. Power supply: Solar cells and rechargeable nickel-cadmium batteries.	Satellite went into predicted orbit, all equipment working as programmed. Period: 101.33 minutes. Inclination to Equator: 50.3 degrees. Velocity at perigee: 17,885 m.p.h. Velocity at apogee: 16,028 m.p.h.	344	678

NOTE.—Distances are in statute miles. Except where indicated, the chart does not include description and weights of spent rocket casings, etc., that have gone into orbits or flight trajectories along with payloads.

Name, by type, orbit weight, payload weight	Lifetime	Launching vehicle	Payload instrumentation	Test results	Altitude
<p>Flioneer, U.S. lunar probe (paddle-wheel spheroid with 4 solar vanes or paddles). Scientific payload: 372 pounds. Mission: To obtain basic measurements of the lunar environment.</p>	<p>Nov. 26, 1959—None.</p>	<p>Atlas-Able. Stages: 1st: U.S. Air Force Atlas ICBM modified to accommodate extra stages. 2d: Liquid propellant, adapted from earlier Able rocket vehicles. 3d: Solid propellant, modified from earlier Able and Vanguard rocket configurations. Gross lift-off weight: 280,000 pounds plus. Height: 98 feet. Diameter at base: 16 feet.</p>	<p>Dimensions: 39 inches in diameter and 55 inches deep with 4 24-inch-by-24-inch square solar vanes jutting from probe's equator. Experiments: (1) Measurements of 3 specific energy levels of cosmic rays; (2) TV-like scanning device to relay lunar surface picture; (3) solar cells (8,800 in all; 1,200 on each side of 4 solar vanes to create voltage to recharge the probe's chemical batteries in flight (Note: electronic gear in probe includes: 2 transmitters and 2 receivers); (4) micrometeroid detector; (5) 2 types of magnetometers; (6) radio wave experiments. Antennas: 4 dipole aluminum rods. Transmitters: 2 ultra-high frequency 378 mc. transmitters at 5 watts. Power supply: Nickel cadmium batteries rechargeable by solar cells (see above). The payload also contained a small engine to provide infinitesimal velocity corrections. The probe payload had two thrust chambers, one to step up velocity, the other to supply reverse thrust when probe approached moon's gravitational field. Each chamber could deliver 20 pounds of thrust.</p>	<p>Countdown was normal and lift-off went as scheduled. 45 seconds after lift-off, 2d stage guidance transmitter no longer responded to interrogation. At 104 seconds, 2d stage telemetry was lost. Atlas booster and sustainer operated as scheduled but, about 45 seconds after launch the plasma shroud covering the lunar probe fell off. As the shroud fell away, the vehicle was approaching maximum atmospheric pressure loads. With the shroud gone, the payload was torn off. Radar indicated that the 2d stage ignited but there was no indication that it separated. The premature shroud separation was caused by inadequate venting of internal pressure beneath the shroud.</p>	<p>Unknown.</p>

TABLE 1.—NASA satellites, lunar probes, and space probes, Oct. 1, 1959–Apr. 1, 1960—Continued

Name, by type, orbit weight, payload weight	Lifetime	Launching vehicle	Payload instrumentation	Test results ¹	Perihelion	Aphelion
Pioneer V (1960 Alpha) U.S. space probe (paddlewheel-spheroid with 4 solar vanes). From A.M.R., Cape Canaveral, Fla. Total payload weight: 94.8 pounds of which experimental instruments comprise slightly over 40 pounds; structure, electronics, and power, the remainder. Mission: To provide information about space between the orbits of Venus and Earth; to test the feasibility of long-range interplanetary-type communications; and to improve methods for measuring astronomical distances.	Mar. 11, 1960— (Lifetime of 100,000 years expected).	Thor-Able. Stages: 1st: Improved Thor IRBM modified for extra stages; 2d: Liquid propellant rocket modified from earlier Vanguard and Thor-Able vehicles. 6 small spin rockets ring its surface. 3d: Solid-propellant rocket adapted from Vanguard and Able I vehicles. Special radio beacon to aid in tracking. Gross lift-off weight: Over 105,000 pounds. Height: 90 feet. Diameter at base: 8 feet.	Shape and dimensions: 26-inch diameter sphere with 4 solar vanes jutting from its equator. Solar vanes are each 18 inches by 14 inches. Shell composition: Fiberglass and aluminum. Experiments: Measurements of—Radiation, magnetic fields, micrometeoroid activity, and temperatures. Transmitters: 2 C HF 378-mc—a 5-watt which on command becomes an amplifier for the second which is a 150-watt transmitter. ² Antenna: Single stub antenna. Power supply: Nickel cadmium batteries rechargeable by the cells on the 4 solar vanes. Each vane carries 1,200 solar cells.	Period: 312 days. Perihelion: 78,000 m.p.h. Aphelion: 63,300 m.p.h. Orbital path: 514,500,000 miles.	74,967,000 miles; Aug. 10, 1960. ¹	92,358,000 miles; Jan. 13, 1961. ¹

¹ Estimates.² The 150-watt transmitter has an output 20-times greater than any transmitter used in prior space experiments. It is designed to permit contact with earth from a 50-million-mile distance.

Name, by type, orbit weight, payload weight	Lifetime	Launch vehicle	Payload instrumentation	Test results	Perigee (miles)	Apogee (miles)
<p>Explorer, U.S. satellite fired from AMR, Cape Canaveral, Fla. Mission: To analyze the energies of electron and proton radiation in the Van Allen radiation zones over an extended period of time. Total payload weight: 22.8 pounds, of which the instrument pack assembly was 12.19 pounds; the instrument housing assembly, 2.47 pounds; the solar cell box, 7.07 pounds; and other assembly items, 0.87 pound. 4th stage casing was to remain attached to the payload. Casing weight was 12.5 pounds, bringing total weight in orbit to 35.3 pounds.</p> <p>TIROS (television and infrared observation satellite) I† (1960 Beta). U.S. meteorological satellite. Launched from AMR, Cape Canaveral, Fla. The satellite is covered on its top and sides by over 9,200 solar cells, 3 pairs of spin rockets and the transmitting antenna are located around baseplate. On top in the center is a receiving antenna. Total payload weight: 270 pounds.</p>	Mar. 23, 1960—None.	<p>Stages: 1st: Modified Jupiter IRBM. 2d: Grouping of 11 scaled-down solid-fuel Sergeants. 3d: 3 scaled-down Sergeants. 4th: Single scaled-down Sergeant. Gross lift-off weight: 120,000 pounds. Height: 76 feet. Diameter at base: 8 3/4 feet.</p>	<p>Dimensions: Cylinder, 21 inches long and 7 inches in diameter. Experiments: Detailed measurements of energetic particles in the Van Allen radiation zones and of temperatures inside and outside the payload. Shell composition: Aluminum. Antenna: Single dipole using payload structure and 4th stage casing. Transmitter: 300-milliwatt operating at 108.03 mc., capable of transmitting data continuously on 5 channels. Power supply: Nickel cadmium batteries recharged by 1,184 solar cells mounted on the box-like structure surrounding the cylindrical instrument package.</p> <p>Dimensions: 42 inches in diameter; 19 inches high, cylindrical in shape. Experiments: 2 TV systems, 1 wide angle, 1 narrow angle, photograph cloud cover and transmit images to earth. Other instruments: Telemetry, command, and an attitude sensor system. Shell composition: Aluminum and stainless steel. Antennas: Turnstile transmitting; 1 receiving. Transmitters: For tracking purposes and providing information on attitude, equipment operation and environment, 23-mw beacon transmitters operating on 108.00 mc. and 108.03 mc. Connected to each TV system is a 2-watt FM transmitter operating at 235.00 mc. for relaying picture information. Power supply: Nickel cadmium batteries charged by solar cells. Transmitter lifetime: 300 hours.</p>	<p>Ground stations lost communications with the vehicle after 2d stage burnout. Launch inclination: 28° to the Equator.</p> <p>Period: 99.19 minutes. Speed: Approx. 18,000 m.p.h. Orbital path: Approximately 27,000 miles. Launch inclination: 48.327° to the Equator.</p>	0	0
	Apr. 1, 1960—(tens of years).	Thor-Able (see Pioneer V.)			435	468

‡ A 12 inch by 12 inch box on which the solar cells were mounted was constructed about the cylinder.

† This is the first of 2 TIROS satellites scheduled for 1960. It is not equipped with infrared radiation sensors to map relative temperatures of the earth's surface. Both satellites are experiments to determine whether meteorological satellites are feasible and to refine instruments and techniques for an operational meteorological satellite system.

CHAPTER 4

NATIONAL LAUNCH VEHICLE PROGRAM

DEVELOPMENT STRESSES POWER, RELIABILITY

To power spacecraft on the varied missions outlined in its long-range plan of space exploration, NASA has been developing a family of launch vehicles with emphasis on thrust, reliability, and versatility.

The group includes Scout, Delta, and the Defense Department's Agena B, Centaur, Saturn, and the Nova concept based upon the F-1 engine. Their payload capabilities range from Scout's 180-pound earth satellite to Nova's 100,000- to 200,000-pound orbital space laboratory.

SCOUT

Scout is a four-stage, solid-propellant launch vehicle weighing 36,000 pounds, designed for a wide range of small-to-medium payload missions—including earth satellites in 300- to 500-mile orbits, space probes, high-velocity entry tests, and advanced heating and ablation studies.

Scout will be capable of launching payloads of 180 pounds in circular west-east orbits at altitudes of 300 miles and of launching probes with 100-pound payloads to altitudes of 6,000 miles.

All Scout components have passed development tests, except the hydrogen peroxide control unit for the second stage which should be ready in May. Assembly of the vehicle will begin in May at Wallops Island; its first flight will take place this summer.

Vehicle

The Scout vehicle consists of four technically advanced solid-propellant rocket stages. The guidance system incorporates gyroscopic stabilization and a built-in, preset program. Controls consist of jet vanes and aerodynamic surfaces for the first stage, peroxide reaction jets for the second and third stages, and spin-stabilization for the fourth stage.

Status

The Scout-first stage rocket (Algol), under development by the Aerojet-General Corp., Sacramento, Calif., weighs 23,600 pounds and has 115,000 pounds of thrust. Four satisfactory test firings have been made; five flight units have been shipped to Wallops Island.

The second-stage engine (Castor), a 9,300-pound rocket with 55,000 pounds of thrust, is being developed by the Redstone Division of the Thiokol Chemical Co., Huntsville, Ala. It is fueled with an improved propellant and has a larger nozzle cone (for improved high-altitude performance) than the Sergeant rocket on which it is based. Twelve test firings have been completed, and six flight units have been shipped to Wallops Island.

The 13,600-pound-thrust third-stage engine (Antares), a scaled-up version of the existing fourth stage, is being developed by the Allegany Ballistics Laboratory at Cumberland, Md. The 2,600-pound rocket has a filament-wound fiberglass engine casing. Although difficulties with insulation and propellant fabrication caused several early failures, the last six firings have been completely successful, and two flight engines have been shipped to Wallops. Two more test firings under altitude simulation conditions in April 1960, will complete the development.

The fourth-stage engine (Altair), developed by Allegany, is a 520-pound rocket with 3,060 pounds of thrust. Because this stage was adapted from the Vanguard upper stage rocket, no development tests are required. Like the third stage, this unit utilizes plastic construction throughout.

Guidance being developed

Guidance for Scout is being developed by the Missile Development Laboratory of the Minneapolis-Honeywell Regulator Co., Los Angeles, Calif. The two hydrogen-peroxide stabilization systems for the vehicle are being built by Walter Kidde Co., Inc., of Belleville, N.J. Guidance development is complete and units have been shipped for early flights. The third-stage peroxide control unit has functioned satisfactorily in tests; however, the second-stage unit has met with valving problems and will not be completed until May 1960. The guidance package and third stage peroxide system were successfully tested at Langley Research Center.

Airframe contract let

The contract for the Scout airframe calls for structurally integrating the rockets, guidance and control systems, and payloads. The task is being carried out by the Vought Astronautics Division of Chance Vought Aircraft Corp., Dallas, Tex. All airframe components, which connect the rocket engines, house the control units and guidance, and cover the top stages, have been fabricated and tested.

Launcher erected

The Scout launcher, fabricated by Vought Astronautics, has been erected on a pad at Wallops Station and has been successfully checked with a mockup vehicle.

DELTA

Delta is a three-stage (first two stages liquid fuel, third stage, solid fuel) vehicle capable of launching a satellite of 480 pounds into a 300-mile earth orbit or a 65-pound payload on a space-probe mission. The first two production Deltas will be used in attempts to launch 100-foot diameter inflatable spheres in Project Echo, the passive communications satellite program. (See ch. 7, "Satellite Applications," pp. 61-65.)

The first complete Delta vehicle was delivered to AMR for launching in May, and its launch facilities were completed.

Vehicle

Delta's first stage is a standard liquid-fuel Thor with 150,000 pounds of thrust; the second stage is a modified version of the liquid-

fuel second-stage rocket engine employed in the Thor-Able vehicle; the third stage is an improved solid-fuel rocket (X-248), also used in the Thor-Able and Atlas-Able, and as the last stage of Scout.

The Delta second and third stages, originally developed for the Vanguard program, were modified and improved for the Thor-Able, and were still further improved for the Delta.

Changes for Delta include the addition of an attitude-control unit, to orient the vehicle in the right direction while coasting; and the Bell Telephone Laboratories radio command guidance unit developed for the Titan program.

ATLAS-AGENA B, THOR-AGENA B

The Agena B, an enlarged and improved version of the Agena A that has demonstrated good reliability in the Air Force Discoverer program, is a liquid-fuel rocket stage having about 15,000 pounds of thrust. It will be used in combination with several different first stages, on a wide variety of missions. Its engines can be restarted in flight.

Agena B, when combined with the 150,000-pound-thrust Thor as first stage, will serve as a general-purpose space vehicle capable of launching 1,600 pounds into a 300-mile orbit. With the Atlas, which gives 360,000 pounds of thrust at lift-off and 80,000 in its sustainer phase, it will be capable of launching 800-pound probes to the moon—including vehicles for "hard" or impact landings on its surface—and 300-mile orbital payloads weighing as much as 5,000 pounds.

Marshall Space Flight Center will technically direct the NASA Agena vehicle program. Lockheed is system contractor. Goddard will provide instrumentation for satellite experiments and the Jet Propulsion Laboratory will design lunar spacecraft.

VEGA CANCELED

Vega was scheduled as an interim vehicle for medium-sized satellite and lunar payloads, pending the availability of Centaur. On December 11, 1959, NASA canceled the Vega in favor of the Agena B under development by the Department of Defense. (See above.)

Vega was planned as a three-stage rocket: First stage, a modified Atlas; second, a modified Vanguard first stage engine; and a third stage powered by a storable liquid-propellant 6,000-pound-thrust engine.

The Jet Propulsion Laboratory directed the project and developed the third stage engine which was not canceled. (See below.) At cancellation, the General Electric Co. had modified the Vanguard engine and the Convair Astronautics Division of General Dynamics Corp., had begun constructing the second stage. Convair was responsible for the overall vehicle integration and implementation of launch operations.

Final termination costs have not been fully determined, but as of April 1, they are estimated to total approximately \$13,300,000. Some of the funds expended on Vega will be recovered by applying its components to other vehicle and test programs. For example, during Vega program work, General Electric produced four usable rocket thrust chambers and a number of engine components, some already

THOR-AGENA B

STAGES

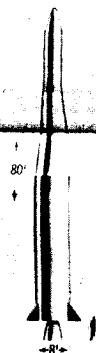
- 1ST STAGE - LOX/RP-1 (THOR)
- 2ND STAGE - IRFNA/UDMH (AGENA B)

MISSION CAPABILITY

300 N. MI. ORBIT - 1,600 LBS.

EMPLOYMENT

METEOROLOGICAL AND
SCIENTIFIC SATELLITES



INITIATED

EARLY 1958 (DOD)

1ST LAUNCHING

EARLY 1962 (NASA)

60-307

ATLAS-AGENA B

STAGES

- 1ST STAGE - LOX/RP-1 (ATLAS)
- 2ND STAGE - IRFNA/UDMH (AGENA B)

MISSION CAPABILITY

300 N. MI. ORBIT - 5,000 LBS.
ESCAPE - 800 LBS.

EMPLOYMENT

LUNAR PROBES
COMMUNICATIONS SATELLITES
SCIENTIFIC SATELLITES



INITIATED

EARLY 1959 (DOD)

1ST LAUNCHING

MID 1961 (NASA)

60-308

SCOUT

STAGES

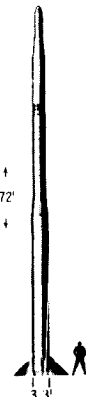
- 1ST STAGE - SOLID (ALGOL)
- 2ND STAGE - SOLID (CASTOR)
- 3RD STAGE - SOLID (ANTARES)
- 4TH STAGE - SOLID (ALTAIR)

MISSION CAPABILITY

300 N. MI. ORBIT 180 LBS.
12,000 N. MI. VERTICAL PROBE 50 LB.

EMPLOYMENT

SATELLITE LAUNCHER
HIGH ALTITUDE SOUNDING
AERODYNAMIC TESTING VEHICLE



INITIATED

LATE 1958

1ST LAUNCHING

MID 1960

5049

DELTA

STAGES

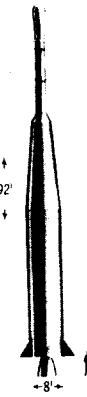
- 1ST STAGE - LOX/RP-1 (THOR)
- 2ND STAGE - WIFNA/UDMH
- 3RD STAGE - SOLID

MISSION CAPABILITY

300 N. MI. ORBIT - 480 LBS
ESCAPE - 65 LBS.

EMPLOYMENT

SATELLITES
SPACE PROBES



INITIATED

EARLY 1959

1ST LAUNCHING

MID 1960

5050

SATURN

STAGES

- 1ST STAGE - LOX/RP-1
- 2ND STAGE - LOX/LH
- 3RD STAGE - LOX/LH (CENTAUR)

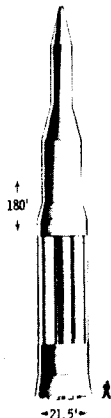
MISSION CAPABILITY

300 N. MI. ORBIT - 25,000 LBS.

ESCAPE - 9,000 LBS.

EMPLOYMENT

LUNAR & SPACE PROBES
24 HR. EQUATORIAL ORBIT
SATELLITES



INITIATED

LATE 1958

1ST LAUNCHING

EARLY 1964 (3 STAGES)

60-125

CENTAUR

STAGES

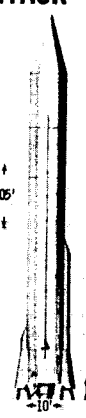
- 1ST STAGE LOX/RP (ATLAS)
- 2ND STAGE LOX/LH

MISSION CAPABILITY

300 N. MI. ORBIT - 8,500 LBS.
ESCAPE - 1,450 LBS.

EMPLOYMENT

LUNAR AND PLANETARY EXPLORATION
24 HOUR COMMUNICATIONS SATELLITE



INITIATED

LATE 1958

1ST LAUNCHING

MID 1961

LD-15

Descriptions, capabilities, and contemplated employment of propulsion systems being developed for NASA's Launch Vehicle Program.

allotted to the Langley Research Center for other projects. A coast-phase test stand for checking the nonpowered phase attitude-control system and a payload shroud jettisoning facility, begun by Convair, will be completed for the Centaur project.

JPL storable-propellant engine

The Vega third-stage 6,000-pound-thrust, storable liquid-propellant propulsion system, upon which JPL was working, will continue under development for future, as yet undesignated, applications. It will use hydrazine and nitrogen-tetroxide propellants fed to the thrust chamber by pressurized gas.

Two types of thrust chambers tested

Two types of thrust chambers that use hydrazine fuel as a coolant have been tested successfully. Plans have been made for testing the ignition and performance of the engine at Lewis Research Center.

ATLAS-CENTAUR

Atlas-Centaur, a two-stage launch vehicle, will be able to inject a communications satellite into a 22,300-mile altitude equatorial orbit. Because the orbital angular velocity of the satellite at this altitude approximates that of the earth's rotation, the satellite will be fixed over one spot on earth. (See ch. 7, "Satellite Applications," pp. 61-65.) The vehicle will also be employed to launch other satellites and lunar and interplanetary probes, in the payload weight range between Atlas-Agena and Saturn.

Liquid hydrogen-liquid oxygen second stage

Centaur's first stage is a modified Atlas D. The second stage is powered by two turbopump-fed rocket engines which produce 15,000 pounds thrust each and utilize liquid oxygen and liquid hydrogen as propellants. This will be the first U.S. engine with a truly high-energy propellant combination. (Saturn's upper stages will use the same combination.) Such propellants will increase the payload capabilities of existing and planned space vehicles up to double those of vehicles with conventional propellants.

Vehicle will have inertial guidance

The Atlas-Centaur all-inertial guidance system will provide, for the first time in a U.S. multistage space launching vehicle, active self-contained guidance throughout powered flight from lift-off to payload injection. The guidance system will permit coasting periods followed by engine restart, to satisfy the orbit requirements of 24-hour satellites and lunar and deep space missions. The system, which will weigh about 150 pounds, employs a four-gimbal platform with three-axis stabilization and a digital computer. (See ch. 13, "Mechanics of Spaceflight," pp. 101-107.)

Marshall Center will direct project

NASA's Marshall Space Flight Center at Huntsville has overall direction of the Atlas-Centaur launch vehicle project. Convair-Astronautics Division of General Dynamics Corp. is developing the Centaur vehicle, integrating vehicle and spacecraft, and will conduct the launch operations. Minneapolis-Honeywell and its subcontractor, Librascope, are developing the guidance system under subcontract

to Convair. Pratt & Whitney Aircraft Division of United Aircraft Corp. is making the liquid hydrogen second-stage engine.

Work is on schedule

Atlas boosters, second-stage engines, and guidance and second-stage structures for the first six Atlas-Centaur flights are now under contract and all work is on schedule.

Tests of a heavy-walled second-stage tank for the liquid hydrogen were begun in November 1959. A second tank planned for ground testing the second-stage engine was completed. A free-floating flight test package was fabricated for use in zero-g experiments in a KC-135 airplane. Purpose of these tests is to study problems associated with storing and pumping liquid hydrogen while in "free fall" encountered in unpowered coasting spaceflight.

Completion of the Centaur launching complex at AMR is planned for late 1960; developmental flights of the Centaur vehicle are scheduled to begin in 1961; and operational flights are planned for 1962.

SATURN

Saturn is the largest launch vehicle under development in the free world. The Advanced Research Projects Agency of the Department of Defense started the project at the Army Ballistic Missile Agency, Huntsville, Ala., in August 1958.

In November 1959, the President decided to assign sole responsibility for developing high-thrust launch vehicles to NASA, which immediately became responsible for technical direction of the Saturn project. ARPA maintained the continuity of administrative direction until March 1960, when this also was assumed by NASA. This was in accordance with the formal notification of Congress, in January, of the proposed transfer of facilities and personnel.

In December 1959, a technical-plus-management committee, comprised of senior personnel from NASA, ARPA, ABMA, and the Department of Defense, recommended that the Saturn upper stages utilize only high-energy propellants (in this case, hydrogen plus oxygen). This combination is known as the Saturn C-1. The Committee also recommended that a building-block approach to upper stage development be employed, so that the smaller, more easily developed stages could be first used atop the large booster, and the number of required engine developments could be minimized. These recommendations were accepted by the Administrator.

Program includes several vehicles

The Saturn program comprises various two-stage, three-stage, and four-stage launch vehicles capable of placing up to 10 tons into a low earth orbit.

The development program has a twofold purpose: (1) To obtain such large payload capability for this country as soon as possible, and (2) concurrently to obtain an early acceptable mission reliability through the use of the clustered-engine technique. The various Saturn vehicles will be useful for orbital missions, including the special case of the 24-hour or "fixed" orbit; for various lunar missions, including soft landing and circumnavigation; and for interplanetary probes.

First stage

The first stage (S-I) of Saturn employs eight Rocketdyne H-1 engines, each delivering 188,000 pounds of thrust at sea level, for a

total thrust of 1.5 million pounds. Liquid oxygen and RP-1 (a hydrocarbon fuel) form the propellant combination; they are carried in a cluster of eight elongated tanks, of the same diameter as the Redstone missile tank, surrounding one elongated tank of the same diameter as the Jupiter tank. The engines can be individually shut off on command when an incipient malfunction is detected. Since the engines are simplified adaptations of the well-proven engines used in Atlas, Thor, and Jupiter, the number of malfunctions during flight is expected to be low. Plans are being developed with the hope of making the booster stage recoverable.

Second stage

The second stage (S-IV) of the Saturn C-1 configuration will utilize the liquid hydrogen-liquid oxygen propellant and four uprated Centaur engines of roughly 17,500-pounds thrust each. The two-stage version of the Saturn C-1 (that is S-I plus S-IV) will be able to place about 5 tons into low orbits.

Third stage

The third-stage (S-V) of the Saturn C-1 is a Centaur upper stage, modified to carry heavier payloads. Two of the same engines which are to be utilized in S-IV are to be used to power this stage. Coasting and engine restart capabilities will be incorporated in this stage, as in Centaur, to permit more difficult orbits and deep space trajectories to be attained.

The third stage will carry an all-inertial guidance system to control all three stages.

Contractors

The Development Operations Division of ABMA has been responsible from the first for the overall technical direction of Saturn. This responsibility will remain with the Division, which—after the planned transfer—will form NASA's Marshal Space Flight Center. It will also be responsible for the detailed "inhouse" development of the booster stage; for integrating the stages and payload, and for conducting launch operations.

First-stage fabrication completed

Fabrication and assembly of the first booster stage, which will be used solely for static testing, has been completed. This stage was mounted in the static test stand in February, after the stand was proof-tested and calibrated. Two of the eight engines have been static tested. Tests of four, then all eight engines will follow. Procurement, fabrication, and assembly of the first three boosters for flight use are on schedule.

Within a month after the decision in December to use high energy propellants in the upper stages of Saturn, an S-IV stage specification was written and industry was invited to submit proposals for its development. Eleven proposals were received at the end of February; evaluation by picked teams of NASA experts was underway on April 1.

Upper stages to follow

A 200,000-pound-thrust, hydrogen-oxygen engine will be developed for the upper stages of the C-2 (or Saturn follow-on configuration) which will employ essentially the same booster as the C-1.

Specifications for the hydrogen-oxygen engine were reviewed with seven engine contractors on February 2 at NASA headquarters. Proposals submitted by five contractors on March 14 were still being evaluated at the end of the report period.

Launch facility nearly complete

Construction of the launch facility for Saturn at AMR began last summer and by April was largely completed. Modifications of the large booster static test stand at Huntsville were completed, as were plans for transporting the booster from Huntsville to AMR by barge. The contract for the first booster transport barge was let.

It was decided that the guidance system for the first three Saturn launches (booster stage only) would be a slightly modified version of the well-proven Jupiter guidance system; investigations of guidance systems for use with the three-stage version are underway.

Full-scale static testing is planned

Full-scale static testing (all eight engines firing) of the prototype booster stage will begin this spring. So also will S-IV stage development and a program to modify the Centaur engines for use in the upper stages of Saturn. Construction work on the launch facility at AMR will be completed this summer, and installation and checkout of special equipment, such as propellant storage tanks, instrumentation networks, and gantries will begin.

F-1 ENGINE

Development of the F-1, single-chamber, 1.5-million-pound-thrust rocket engine by the Rocketdyne Division of North American Aviation, Inc., began in January 1959. The development phase should be completed in early 1963.

Engine static tested

The primary effort during this report period has concentrated upon developing the engine's large-scale thrust chamber. Static tests of up to 3 seconds duration have produced thrusts of more than a million pounds. Although performance has approached acceptable limits, it has frequently been erratic and work is continuing.

Propellant pumps are on schedule

The turbine-driven propellant pump assembly is on schedule. Tests on a scale model indicate that the desired performance can be met. Designs have been incorporated which will facilitate the fabrication of the various components of the turbopump.

Several system changes, particularly in the propellant inlet section of the engine, have been made. These in turn have been incorporated in the mockup of the F-1 engine. A study of ways to cool the large F-1 exhaust nozzle is nearing completion; one method involves the use of the relatively cool turbine exhaust gases next to the nozzle wall. It is possible that only the upper portion of the nozzle need be cooled by one of the propellants.

Construction underway on three test stands

Work is continuing on the three stands intended for F-1 engine testing at the missile captive test site, Edwards Air Force Base, Calif. These will permit extending present test limits of about a million

pounds of thrust and 3 seconds maximum duration imposed by equipment now in use. Stand 2A will be ready soon and the first firing of an F-1 thrust chamber should take place in July. Having stand 2A available for this project will expand the scope of work appreciably.

SOUNDING ROCKET DEVELOPMENT

NASA space science investigations require a family of sounding rockets to carry scientific payloads of numerous types to various altitudes.¹⁰ Prototype rockets of a projected series are the "Arcon" and "Iris." Initially, they were projects of the Naval Research Laboratory (NRL) and the Navy Bureau of Ordnance. Now directed by NASA's Goddard Space Flight Center, Arcon and Iris development is being carried out under contract to the Atlantic Research Corp., Springfield, Va.

ARCON

Six inches in diameter and 8 feet 6 inches long, the Arcon rocket weighs 220 pounds, and uses a fast, end-burning solid propellant. A stabilizing fin section and a 40-pound, instrumented payload are attached to form a vehicle 11 feet long, weighing 254 pounds. The Arcon vehicle was designed to lift its payload to an altitude of 70 miles. NASA development, consisting of improvements in chamber insulation and propellant-charge design, was completed in 1959.

After the results of the six flight tests performed in mid-1959 were evaluated, two problems were evident: (1) aerodynamic surface redesign is necessary to eliminate erratic performance which occurs as the rocket nears burnout; and (2) the rocket power will have to be increased if the original altitude goal of 70 miles with a 40-pound payload is to be met. Three more vehicles remain to be flown in the Arcon development program, probably by mid-1960.

IRIS

Substantially larger than Arcon, the Iris rocket is also being developed by Atlantic Research Corp. Designed to propel a 100-pound payload to an altitude of 185 miles, the rocket is approximately 13 feet long, 1 foot in diameter, weighs 1,140 pounds, and uses the same propellant as Arcon. A stabilizing fin section and a 100-pound payload are attached, resulting in a 1,290-pound vehicle, 20 feet long. Launched from a tower, the rocket will be given extra initial thrust by a small clustered booster.

Several firings of test chambers during this period proved the integrated design. Three engines were static-fired successfully. Four more rounds will complete the ground test program. Three operational vehicles will be assembled in May-June 1960, and flight tests will begin. Ballistic and aerodynamic data available at this time indicate that the desired performance will be attained.

The NASA Propulsion Office at Headquarters has technical management of sounding rocket development. The Goddard Space Flight Center participates in aerodynamic design, supplies payloads, and will conduct flight tests at Wallops Island.

¹⁰ In comparison with other NASA vehicle programs, the payload and altitude requirements are relatively low. Mission requirements are to reach various layers of the atmosphere and ionosphere, usually below 200 miles. Instrumentation required is likewise less elaborate than that for space missions.

CHAPTER 5

MANNED FLIGHT IN SPACE AND NEAR SPACE

THE NEED FOR MANNED SPACE EXPLORATION

Electronic instruments designed for NASA satellites and space probes can perform many intricate, ultraswift, ultra-accurate tasks of sensing and measuring better than men could ever do. However, the statistical information gathered and transmitted to earth by these instruments constitutes only a part of the basic research necessary for understanding the larger realities of space. The most advanced apparatus can perform only as it is programmed to do. Instruments have no flexibility to meet unforeseen situations. Scientific data acquired in space mechanically must be balanced by on-the-spot human senses, human reasoning, and by the power of judgment compounded of these human elements.

In this lies man's superiority to the machines he invents and builds. And in that superiority lies the necessity for manned space flight, as soon as it is practicable. But before man can fly to the moon and beyond, the question of his ability to withstand the rigors of space-flight—weightlessness, high-g forces, atmospheric entry forces, etc.—must be answered. These are the reasons for the top national priority that has been assigned to Project Mercury.

PROJECT MERCURY

SUBORBITAL FLIGHT PLANNED

For the next 2 or 3 years, NASA has planned about 20 testing, training, and orbital flights in Project Mercury. According to present schedules, NASA plans the first manned suborbital flight for late this year, and the first manned orbital flight for later in 1961.

REDSTONE WILL LAUNCH CAPSULE

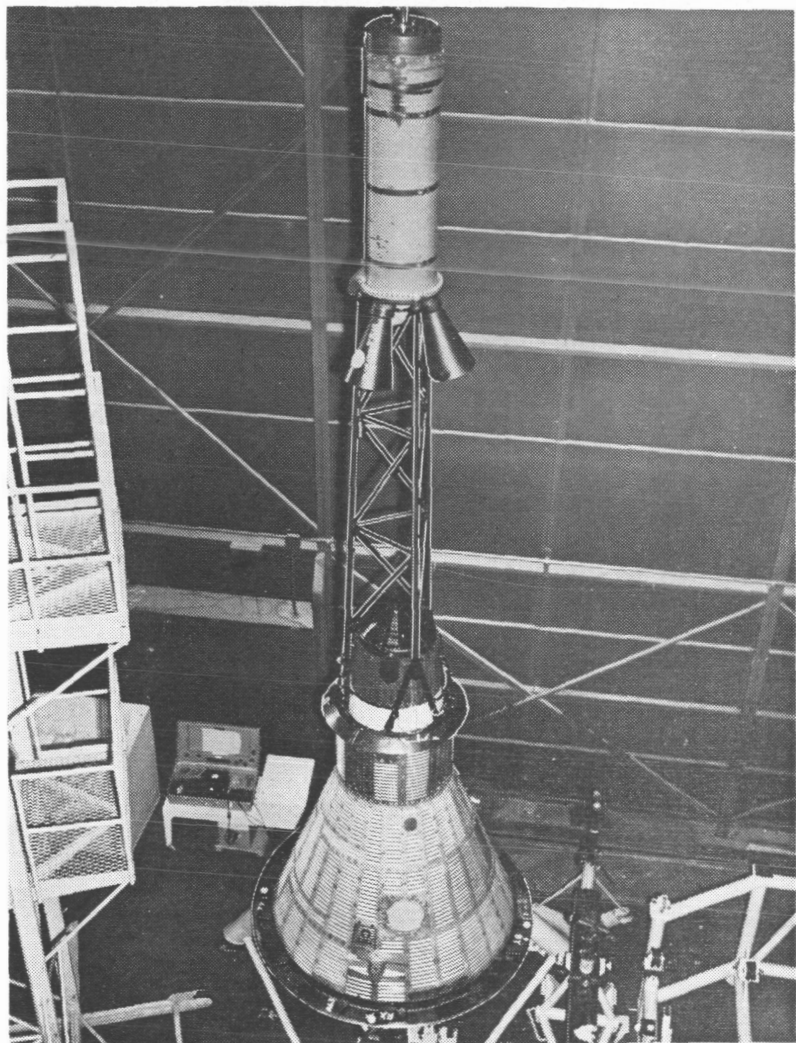
In the suborbital test, a Redstone rocket will launch a manned Mercury capsule from Cape Canaveral on a 15-minute flight down the Atlantic Missile Range at speeds up to 4,000 miles per hour. The astronaut will experience about 5 minutes of weightlessness, reach an altitude of 120 miles and a distance of 180 miles, landing in the sea off Florida.

ORBITAL FLIGHT PLAN

Plans for the first manned orbital flight call for the Mercury capsule to be boosted into orbit by an Atlas launched from AMR in a direction slightly north of east. This trajectory will send it into orbit at a point in space over Bermuda. The capsule will travel at a speed of about 18,000 miles per hour, at an altitude of about 100 miles over Africa, Australia, Mexico, and the United States.

A worldwide system of tracking and communication stations will be in contact with the Mercury capsule almost continuously.

Near the California coast, after three circuits of the globe, retro-rockets will be fired, either by the astronaut or by radio command from the ground, slowing the capsule by 350 miles per hour so that



The first production model of the Mercury capsule with its escape system (incorporated in the pylon mounted on the capsule).

it will return from orbit and become susceptible to atmospheric drag. Within one-quarter of a circuit, this drag will reduce the capsule speed below 200 miles per hour so that landing parachutes can be safely deployed. Opening at an altitude of about 10,000 feet, the parachutes will lower the capsule at the rate of 30 feet per second to a landing in the Atlantic Ocean near the Bahama Islands.

After the capsule strikes the water, the parachute will be detached automatically. The capsule will float. The entire flight, about 75,000 miles, will have lasted $4\frac{1}{2}$ hours—about the time it takes a jet airliner to fly from Los Angeles to New York.

Government aircraft and ships will be deployed within the landing area to recover the capsule and its astronaut passenger.

PROGRESS

During this period, the following major advances were made in Project Mercury:

The escape system was confirmed by four test launchings with "Little Joe" rockets.

The first space capsule was delivered to Wallops Station, Va., by the contractor, McDonnell Aircraft Corp., St. Louis, Mo.

Various modifications of the capsule were made, including a window (21 by 11 inches) to replace two small portholes, a quick-opening emergency escape hatch, and an inflatable landing bag to reduce shock in case of a land impact.

Prototype Goodrich full-pressure suits for astronaut wear were delivered to NASA in November.

Astronaut training progressed on a broad front, including "zero gravity" flights in aircraft, centrifuge experience, engineering studies, etc.

A series of parachute tests were made by aircraft and helicopter in the capsule parachute qualification program.

Other components of the Mercury system, including the retrograde rocket motors, were tested. (See below.)

LITTLE JOE FLIGHT TESTS

Little Joe is a fin-stabilized, clustered, eight-rocket launch vehicle consisting of four modified Sergeant and four Recruit rockets, designed for ballistic flight tests of boilerplate models of the Mercury capsule and operation of the escape system under severe conditions. The rocket has a maximum velocity of about 4,000 miles per hour and a range of 160 miles.

Little Joe has proven to be a valuable and reliable test vehicle. The rocket performed satisfactorily in all four tests during this report period. Boilerplate capsules, used in Little Joe and in landing system drop tests, duplicate weight and external shape of the capsule. Constructed of heavy, welded sheet steel, they contain some instrumentation, but not the many subsystems with which the final capsule will be equipped. The boilerplate capsules provide an economical means of developing parachute and escape systems, checking out recovery procedures, and determining capsule motions and heating.

First test

On October 4, 1959, a Little Joe vehicle carrying a boilerplate Mercury capsule with a dummy escape system was launched from Wallops Station. This flight attained its objectives of checking the soundness of the booster airframe and rocket engine system, the operations of the rocket and the emergency "destruct" system. After confirmation of satisfactory vehicle performance, the destruct system was triggered, $2\frac{1}{4}$ minutes after launch.

Second test

On November 4, NASA launched a second Little Joe from Wallops Station to test the escape system under severe dynamic pressure. The launch vehicle functioned well, but the escape rocket ignited several seconds too late. By that time, aerodynamic pressure had fallen from its maximum of 1,000 pounds per square foot to 200 pounds per square foot. The test failed to achieve its primary objective.

Other purposes of the firing were to test parachute operation and recovery. Both the drogue (ribbon) and the main parachutes functioned properly, opening as programmed. The main parachute was automatically detached when the capsule landed. After this test, a revised igniter was designed and simulated altitude tests of the revised ignition system were made in the Arnold Engineering Development Center Facilities at Tullahoma, Tenn.

Third test

A third Little Joe test took place on December 4. The launching, at 11:15 a.m. eastern standard time from Wallops Station, carried the capsule to an altitude of 55 miles. Purpose was to check operation of the escape system at high altitude. The escape rocket fired at an altitude of 95,000 feet, just after Little Joe burnout. Escape acceleration was 15 g.

The capsule contained a biopack (a container with equipment to support life) carrying a rhesus monkey. A ship retrieved the capsule from heavy seas at 1:15 p.m. All location and recovery equipment on the capsule performed successfully. The monkey, which had experienced 8 g at launch and 15 g when the escape rocket fired, was recovered alive and well.

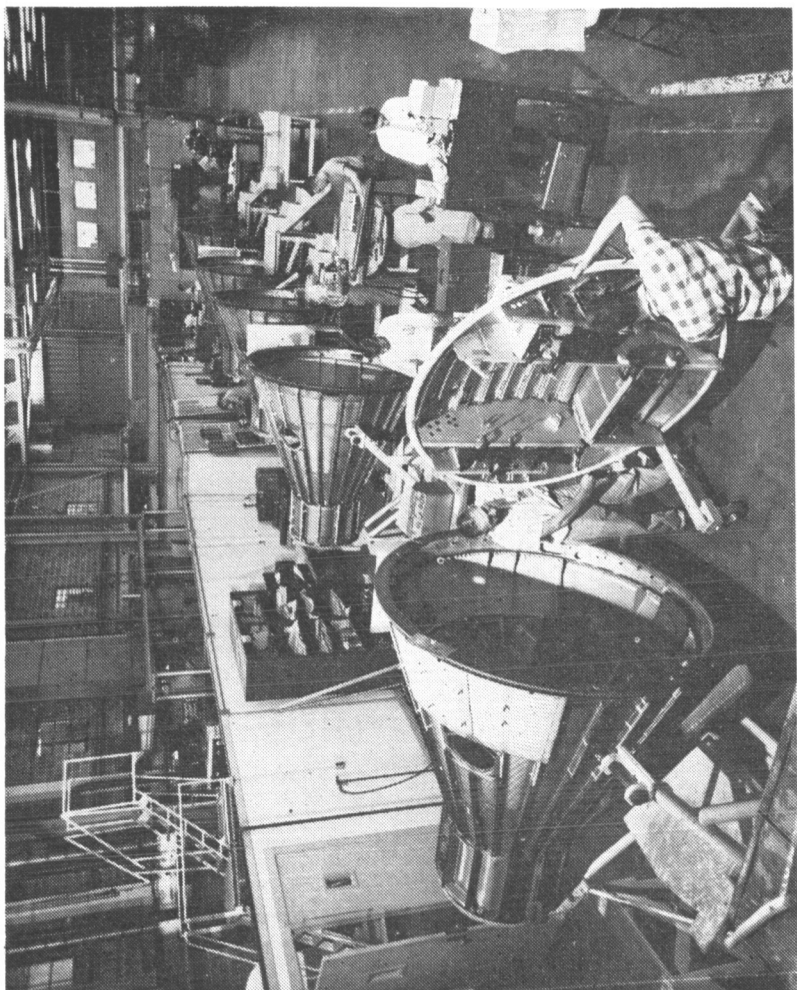
Fourth test

The fourth Little Joe vehicle was launched on January 21, 1960, at 9:23 a.m. eastern standard time from Wallops Station. The principal objective of this flight was the same as that of the second Little Joe; namely, to check the performance of the Project Mercury escape system at maximum aerodynamic stress conditions. The capsule carried a 6-pound rhesus monkey in a test of primate reaction to high acceleration forces.

The escape system, which was triggered by radio signal from the ground, ignited at 36,500 feet, withstanding 1,070 pounds of air pressure per square foot as it carried the capsule away from the booster. A timing mechanism separated the escape tower from the capsule at 48,900 feet. The capsule's parachutes opened on schedule and the capsule landed in the Atlantic Ocean 12 miles from Wallops Station. Total flight time: 8½ minutes. A helicopter recovered the capsule within 5 minutes of landing. This flight confirmed the satisfactory performance of the Mercury escape system.

MCDONNELL DELIVERS FIRST CAPSULE

The first production model of the Project Mercury space capsule was delivered to Wallops Station, Va., on April 1 by the contractor, McDonnell Aircraft Corp., St. Louis, Mo. The capsule, first of 24 contracted for, is instrumented for escape system tests to be conducted by NASA's Space Task Group.



Project Mercury capsules are assembled at the McDonnell Aircraft Corp., St. Louis, Mo.

Capsule made safer

A number of changes have been made in the capsule to render it safer. First, an air cushion has been added to provide additional impact protection in case the capsule lands on the ground instead of the water (which could occur, for example, in an abort off the launch pad). This cushion consists of an extendable, 4-foot-long skirt of rubberized fiberglass connecting the heat shield with the capsule structure.

After the main parachute is deployed, the heat shield is released from the capsule and the bag fills with air. Upon impact, the air trapped between the heat shield and the capsule vents through the holes in the skirt, thereby providing the desired cushioning effect.

The impact bag also increases the vehicle's stability in a water landing, serving as a sea anchor, and thus preventing the capsule from pitching too actively.

Enlarged window provided

An enlarged window, 21 by 11 inches, has been added to replace two smaller portholes. This will allow the astronaut, in case other systems fail, to observe the orientation of the vehicle; it will also provide him with visual reference for controlling his position during retrorocket firing.

Emergency hatch added

In addition to the top hatch, provision has been made for a quick-opening emergency hatch within the side door, which is bolted in place. The hatch is opened by means of explosive bolts. The pilot can trigger the side hatch from the inside, much as a canopy is blown from a jet fighter plane.

CAPSULE ESCAPE AND RETROGRADE ROCKETS

Both the capsule and retrograde rockets have been successfully fired under simulated space conditions at the Arnold Engineering Development Center wind tunnel, Tullahoma, Tenn. In addition, the capsule escape system rocket has been successfully tested under the most critical capsule escape conditions in flight. The retrorocket has not been evaluated as yet under flight conditions. The development of both the capsule escape and retrograde rockets is essentially complete and qualification of these units is underway.

PARACHUTE TESTS CARRIED OUT

More than 100 parachute tests have been made to date with aircraft and helicopters. The parachute qualification program is nearing completion. In a typical test, the 1-ton test capsule is dropped from a transport aircraft and lands at a rate of 30 feet per second. After water contact, the chute automatically releases itself and the test capsule remains afloat until recovered.

ENVIRONMENTAL CONTROL SYSTEM TESTS

The environmental control system must maintain a livable atmosphere within the capsule under space conditions. The first manned developmental system tests were completed in November 1959, at

the AiResearch Manufacturing Division, Garrett Corp. These tests were conducted in an altitude chamber to determine the proper functioning of all system components. Preliminary data from these tests indicate that the system operated satisfactorily.

ASTRONAUT PRESSURE SUITS DELIVERED

Prototype Goodrich full-pressure suits for astronaut wear during Mercury flights were delivered to NASA in November. These are modified Navy Mark IV suits. The Navy Air Crew Equipment Laboratory (NACEL), Philadelphia, Pa., fitted the suits to the astronauts and indoctrinated them in their use.

Tests of the suit at simulated high altitudes and at high temperatures have shown that it effectively resists heat. NASA, NACEL, and the Goodrich Co. are continuing developmental work on the suit.

After receiving their pressure suits, the astronauts visited the McDonnell Aircraft Corp., St. Louis, Mo., to be individually fitted with special couches on which they will lie during the mission.

ATTITUDE SENSING AND REACTION CONTROL SYSTEMS

The attitude sensing and reaction control systems must stabilize the capsule in the proper rotational position in space. Horizon scanners are used in conjunction with gyroscopes and appropriate electronic circuitry to sense attitude of the capsule.

Simulated mission tests of the complete attitude sensing system were begun in mid-January. For these laboratory tests an artificial horizon was used. Performance of the completed system was proven satisfactory in tests made to date.

In order to permit rotational movement of the capsule, small hydrogen peroxide rocket jets, built by the Bell Aircraft Co., are provided. Successful tests of these small reaction jets have recently been completed at the Lewis Research Center.

COMMUNICATIONS (ON-BOARD) AND INSTRUMENTATION

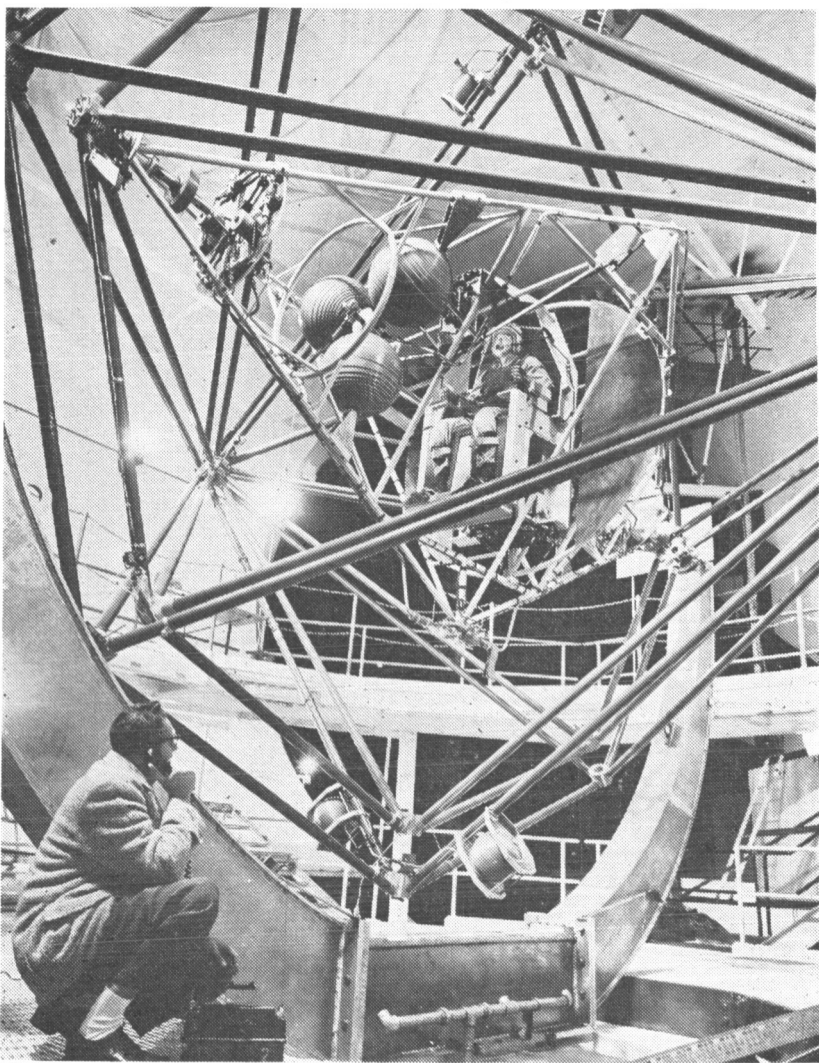
During the last 6 months, extensive field trials of the several communications systems in the capsule have been completed.

BIG JOE FLIGHT TEST RESULTS

Detailed results of the Big Joe launch of September 9, 1959, have been assessed. In that test, an Atlas boosted a full-scale instrumented boilerplate model of the Mercury capsule to near-orbital speed and an altitude of about 100 miles. The purpose was to test entry capabilities, performance of the heat shield, capsule flight characteristics and capsule recovery.

The heat shield successfully withstood entry, thereby proving the design. The Big Joe flight test results have been used in conjunction with results obtained in the Ordnance Aerophysics Laboratory heated jet tunnel at Daingerfield, Tex., to evaluate the afterbody heating problem. The most significant result is an indication that under the most critical abort entry conditions the afterbody heat shielding in certain areas may be marginal. Appropriate changes are being made to the heat shielding design in these areas.

Besides the heating data obtained from the Big Joe flight test, important aerodynamic stability data were derived. The capsule's stability (inherent tendency to keep the heat shield forward) proved better than had been anticipated.



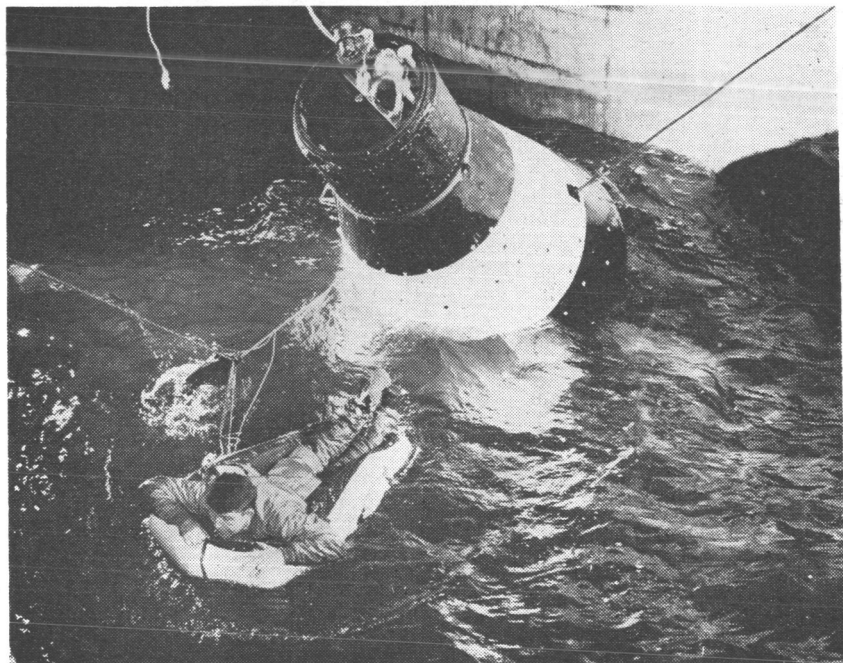
The multiple-axis space test inertial facility in which Mercury astronauts experienced the pitch, roll, and yaw of simulated space flight is tested at Lewis Research Center.

ASTRONAUT TRAINING PROGRESSES

The biological effects of the weightlessness that the astronauts will experience in orbital flight are largely unknown. During this period, as part of the training and familiarization program, each astronaut made four "zero gravity" flights in F-100F aircraft. By

flying a ballistic trajectory, the aircraft can produce weightlessness for as long as 60 seconds.

Each astronaut made his first two flights as a passenger, first wearing a regular flying suit, then a Mark IV pressure suit. On the third flight, the astronaut was at the controls, and the final flight was a repetition of the first, to permit comparison in performances. The astronauts and the aircraft were instrumented; physiological and other data were telemetered to the ground. During weightless flight, the astronauts took solid food (ground meat, etc.) from toothpaste-like tubes and drank water from a squeeze bottle and another type of experimental bottle. The space foods and containers were developed by the Army Quartermaster Corps.



Astronaut practices escape from capsule in a simulated ocean landing.

Initial studies of collected data show no unusual reactions during weightless periods. The astronauts reported no difficulty in flying the airplane or in eating during weightless flight.

Manned centrifuge experiments

Each astronaut experienced about 10 hours of simulated flight in the manned centrifuge at the Navy Aviation Medical Acceleration Laboratory, Johnsville, Pa., at accelerations as high as 18 g. While whirling in the centrifuge cab, the astronauts controlled the vehicle attitude with the manual controller which fed signals through an analog computer. They developed breathing techniques that prevented blackout and permitted them to control the vehicle actively despite the high acceleration.

Static flight simulator training

At Langley Research Center, the astronauts were trained in a fixed-base simulator with computer-driven instruments which permitted the astronaut to practice capsule orientation during orbit, retrofire, and entry into the atmosphere.

Heat and pressure chamber familiarization

Each astronaut also spent several hours in a combination pressure and heat chamber which realistically creates the conditions expected in the Mercury capsule during entry. The astronauts wore pressure suits during these tests, which were conducted at the Navy Air Crew Equipment Laboratory, Philadelphia, Pa.

Basic studies completed

By December 31, the astronauts had completed basic and theoretical studies in their training program and had started practical engineering studies. This involved, for example, a transition from the theory of propulsion to study of actual propulsion systems.

Areas in the training program include such subjects as astronautics, electronics, trajectories, guidance, rockets, and scientific observations during orbital flight. As part of the training, the astronauts visited industrial and Government facilities engaged in rocket research and development and other space flight work.

Visit planetarium

The astronauts visited Morehead Planetarium in Chapel Hill, N.C., where they took a short course in celestial navigation and recognition of stars.

Their training also included experience in the multiple axis attitude control facility at Lewis Research Center in Cleveland. In the facility, which simulates roll, pitch, and yaw motions simultaneously, the men experienced more severe tumbling acceleration and velocities than are expected in Mercury capsule flight.

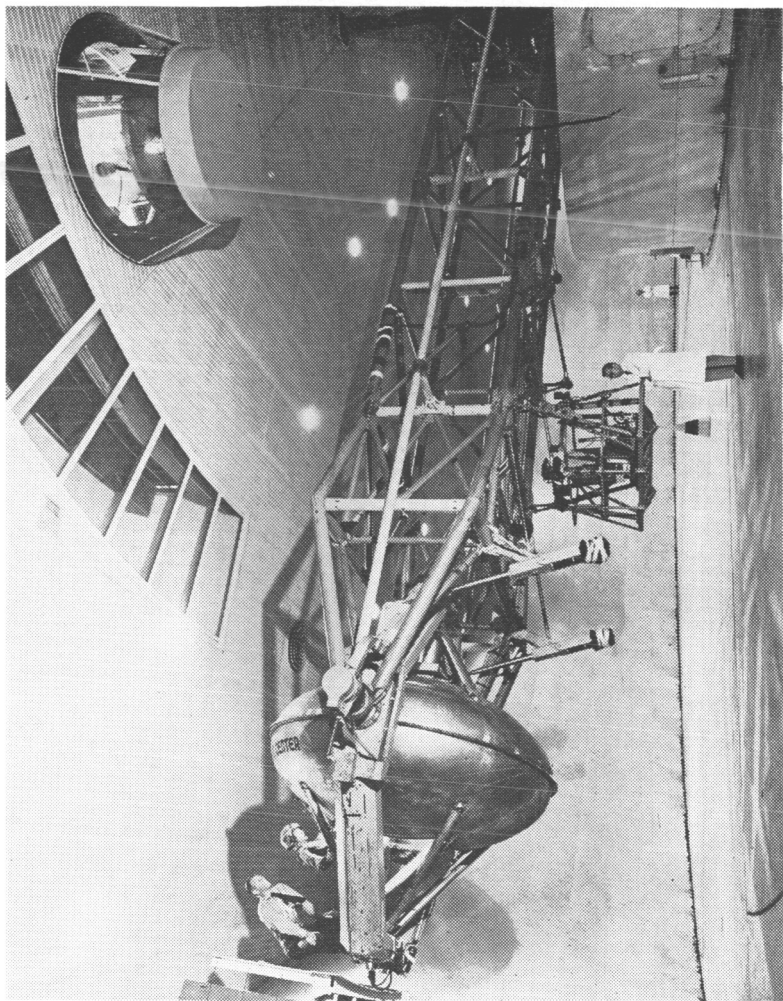
Capsule egress training was conducted in the Gulf of Mexico off Pensacola, Fla. Although 10-foot swells were experienced, no major problems were encountered. The astronauts also trained with life-rafts and other survival gear.

MERCURY TRACKING NETWORK PROGRESS

The mission of the Mercury tracking and ground instrumentation network is to provide all functions for the ground control and monitoring of Mercury suborbital and orbital flights from launch to landing. When completed, it will be capable of providing tracking, telemetry, command control, and communication coverage of the Mercury capsule on a three-orbit mission.

Network responsibilities

Mercury network responsibility is as follows: The Space Task Group of Goddard Space Flight Center has overall responsibility for Project Mercury; the Instrument Research Division of Langley Research Center has the NASA responsibility for planning and designing the network; the Department of Defense lends the support of several of its range instrument stations as does the Weapons Research Establishment of the Australian Government.



Mercury astronaut prepares to undergo stresses, simulating acceleration and entry, in the centrifuge at the Naval Air Development Center, Johnstown, Pa.

Final operational control of the network during mission operations will be under the direction of a NASA representative. The Western Electric Co., Inc., has the prime contract for the implementation of the net.

The total cost of the network will be \$50 to \$53 million. The network should be operational by early 1961.

Planning and design completed

Progress through this period included completion of network planning and design. All station site surveys have been made and foreign station negotiation has progressed satisfactorily. The decision between a ship or land station in the west Mexico area has been made in favor of the land installation as a result of favorable negotiations with the Government of Mexico. Construction has started at several sites, including the Bermuda station, which has an early operational readiness date to accommodate suborbital missions.

Ground communications readied

Planning and arranging for ground communication links between stations is also progressing. Letters of intent have been issued to several domestic and foreign commercial communications agencies to begin carrying out this work.

Production of electronic equipment for outfitting the stations has begun. Modification of surplus SCR-584 radars to the Verlost (very long range tracking) radar configuration is proceeding on schedule. Mockups of display and control consoles for final engineering approval prior to production have been completed.

An agreement was reached on March 19 with Spain concerning establishment of a Mercury tracking station in the Canary Islands and construction is scheduled to begin in April 1960. The activity at this station will be carried out in collaboration with the Instituto de Técnica Aeronáutica, of the Spanish Air Ministry.

THE X-15 RESEARCH AIRPLANE

PLANE NO. 1 TRANSFERRED TO NASA BY CONTRACTOR

On February 19, 1960, the X-15 research airplane No. 1 was delivered to NASA by the contractor, North American Aviation, Inc., Los Angeles, Calif. To this date, all test flights had been by the contractor to develop and prove the capability and reliability of the airplane with the interim engine.¹¹

On March 25, NASA test pilot Joseph A. Walker flew the X-15 No. 1 for the first time under NASA-Air Force-Navy auspices. The familiarization flight began a planned series that would eventually bring the X-15 to its maximum speed and altitude goals with the interim engine.

¹¹ The XLR-11 interim engines, two of which are used, produce 8,000 pounds of thrust each; the final XLR-99 engine will have 50,000 pounds of thrust.

X-15 NO. 2 REACHES NEW PEAK ALTITUDE

Meanwhile, on February 11, X-15 No. 2 reached 86,000 feet, highest altitude yet for this airplane, also powered with interim engines. Scott Crossfield, the contractor's test pilot, was at the controls. The following week, the pilot subjected the craft to roll maneuvers at speeds as high as Mach 1.56, and on March 17, subjected it to still more severe stresses.

DEMONSTRATION FLIGHTS CONTINUED

Two additional contractor demonstration flights were made to determine effectiveness of the stability augmentation system. Both flights achieved a maximum Mach number of 2.0 and a peak altitude of 50,000 feet. Launching of the No. 2 airplane on March 29, 1960, was preceded by a long cruise at 35,000 feet to "cold soak" the airplane (bring it gradually to a low temperature and sustain it there for test purposes) to simulate later launching from Wendover AFB, Utah. All systems operated well. Engine-start after launching was satisfactory. On March 21, 1960, another flight of the No. 2 airplane gave proof of good stability and control characteristics. Approach and landing were as planned.

XLR-99 ENGINE GROUND TESTS

Reaction Motors Division of Thiokol Chemical Co., contractor for the final XLR-99 engine for the X-15, reported successful completion on February 16 of a series of 36 tests at the Arnold Engineering Development Center, Tullahoma, Tenn. Tests included evaluation of starting characteristics, idling, heat transfer and ignition properties. Numerous types of malfunction were simulated to test the engine's safety features. During flight, the XLR-99 engine can be stopped and restarted, and its thrust can be varied.

CHAPTER 6

SPACE SCIENCES RESEARCH

NATURE OF ACTIVITIES

Among NASA's better known research tools are its sounding rockets, satellites, and deep space probes. These are highly instrumented devices for measuring the phenomena of the earth's atmosphere and space environment. Dispatched on space missions, they sense, record, and transmit fundamental information on the structure and contents of the universe.

In effect, the sun and planets and the space in which they exist are natural laboratories where experiments on matter and energy are constantly in process under extreme conditions and on enormous scales. Information accumulated from missions into these gigantic laboratories is essential to scientific and technical progress and to add to man's store of knowledge.

This chapter recounts progress in some of the more important phases of this NASA endeavor.

PROGRESS

During the period, there was substantial NASA activity over a broad range of work related to the space sciences:

1. The scientific satellite Explorer VII and the ultra-long-distance solar orbiter Pioneer V succeeded. (For details, see ch. 3, "Experimental Missions," pp. 9-27.)

2. NASA began to make available to scientists throughout the world a description of the techniques needed to record the telemetering codes of Explorer VII.

3. NASA released results from partial analyses of data transmitted by Vanguard III—launched September 18, 1959—and Explorer VI—launched August 7, 1959.

4. Staff scientists of NASA participated in the First International Space Symposium of the International Committee on Space Research (COSPAR), Nice, France, January 8-16, 1960. Scientific highlights of the conference appear below. (For other information see ch. 9, "International Programs," pp. 70-72.)

INTERNATIONAL SCIENCE ACTIVITIES

FIRST INTERNATIONAL SPACE SYMPOSIUM

During the 8 days of meetings at Nice, more than 100 papers were delivered and discussed by delegates from many nations. U.S. scientists contributed approximately 40 of the papers, of which NASA delegates delivered 12. Many U.S. papers were by members of university faculties or other groups wholly or partly supported by NASA research grants.

The range of subjects was broad, extending from discussions of rocket meteorological measurements and the nature of the earth's atmosphere to cosmic radiation and interplanetary gas. Rocket and satellite investigations of the ionosphere and of the earth's magnetic field were covered, as were solar radiation, the auroras, and airglow phenomena. Separate sessions were devoted to the moon and the planets, and to meteoroids and interplanetary dust. Scientific results obtained from the Explorer, Vanguard, and Pioneer series were presented by U.S. scientists. Soviet scientists reported information from their satellites and lunar probes. Scientists of other nations gave results from sounding rocket and laboratory experiments or from theoretical studies.

EXPLORER VII TELEMETERING CODES RELEASED

In keeping with the U.S. objectives of encouraging world cooperation in space exploration, in January NASA made available to interested scientists descriptions of equipment and techniques for receiving and recording data from Explorer VII. As the period ended, plans were being made to give out the details of calibrations used for the experiments carried by the satellite. This will enable scientists the world over to obtain from their own recordings of Explorer VII transmissions calibrated data from which they can make their own analyses of space phenomena.

SCIENTIFIC RESULTS TO DATE

NATURE OF RADIATION REGION STILL CONJECTURAL

At its present stage, space research has just begun to reveal the complexity of the phenomena being studied and to provide some understanding of the interrelations among these phenomena. For instance, it is now known that the earth-girdling Great Radiation Region—discovered by James A. Van Allen—undergoes drastic changes in extent and intensity over periods of months. Moreover, great fluctuations have also been recorded in a few hours. Apparently, some of the changes result directly from increases and decreases in solar activity. Other variations in the earth's radiation zones do not appear to be related to solar disturbances. Although information is flowing in from each new experiment, the sources and nature of the particles in the radiation region are still only partly understood.

EARTH'S MAGNETIC FIELD RELATIVELY STABLE

Data from the magnetometer carried by Vanguard III have delineated the magnitude and direction of the earth's magnetic field in the region covered by the satellite's orbit (between altitudes of about 320 and 2,330 miles, latitudes of 33° N. and 33° S.). At these altitudes, the magnetic field has been found to be stable for long periods, although some short-term fluctuations have been detected that require more theoretical and experimental study.

HAZARDS TO LIFE AND SPACECRAFT EVALUATED

It seems fairly certain that the radiation surrounding the earth will be a serious hazard for manned flight. Perhaps rapid passage through the radiation region will prevent serious biological damage. A greater danger to manned space flight may lie in the sudden bursts of energetic particles and X-rays hurled out from the sun at times of solar eruptions. These concentrated bombardments cannot be predicted. They seem to erupt at random and range in all directions through immense distances of space.

So far, space exploration has shown that meteoroids and micro-meteoroids will produce only negligible damage to satellites and probes. It also appears that temperatures of the simpler space probes and satellites can be maintained within desired limits by engineering design. Not yet has it been possible to predict accurately at what rates the effects of the radiation belts will shorten the life of solar cells. Indications are, however, that if protective coverings are used, damage may not be fast or extensive enough to make solar cells impractical for satellites and probes traveling in the radiation region. Vanguard I solar cells are still operating after having been subjected to this radiation for more than two years.

SUNLIGHT PUSHES FIRST VANGUARD

Recent NASA findings from a detailed study of the orbit of Vanguard I—launched March 17, 1958, and still transmitting—show that sunlight in space exerts enough pressure to shift the course of the satellite by about 1 mile per year. The discovery is as important as it is unexpected. Although science has long known that light exerts minute pressure, no one foresaw that the force of solar radiation could affect the orbit of a satellite to such an extent in such a short time.

EARTH'S PEAR SHAPE CONFIRMED

That the earth is slightly pear shaped was again shown by study of the orbit of Explorer I. This confirmed results obtained originally from the Vanguard I orbit. (See NASA's First Semiannual Report to Congress, October 1, 1958–March 31, 1959.)

RADIATION AFFECTS WEATHER

Significant correlations seem to exist between incidence of radiation and abnormal heating of the atmosphere. This may account for some of the correlations of terrestrial weather with solar surface activity. There is also evidence of a relation between the radiation region and auroras.

SPACE RESEARCH PROGRAMS

NASA space science research is going forward in two principal areas: (1) Satellite and sounding rocket programs and (2) lunar and planetary programs. The primary aim is to increase man's knowledge by investigating the earth's atmosphere and the space beyond by means of rockets and satellites. As indicated earlier, the characteristics of the atmosphere and space are broadly defined by employing a wide variety of exploratory instruments. Once this is done, scientists can

design advanced, highly specialized, and accurate instruments for more detailed investigation.

SATELLITES AND SOUNDING ROCKETS

Geophysics and astronomy

Scientific investigations carried out by satellite and sounding rockets fall into two main groups: (1) Geophysical studies of the earth's upper atmosphere, the immediate space environment of the earth, and the role of solar phenomena in relation to terrestrial phenomena; (2) astronomical studies. Astronomy is one of the oldest of scientific disciplines. From it have come age-old and incalculably great benefits. As examples, from ancient observation of the heavenly bodies we learned to measure time, to navigate the seas, and to devise calendars.

Atmospheric veil pierced

Since man first began studying the sun, moon, and stars, his investigations have been hampered by the absorbing effects and the distortions of the earth's atmosphere. Distortion of objects seen through the shimmer of midsummer heat is a familiar example. Sounding rockets and satellites can carry above the veil of atmosphere many types of instruments to study the heavens.

Even though the era of artificial satellites is less than 3 years old, spectacular phenomena have already been discovered. Because scientific research is the investigation of the unknown, it is impossible to predict exactly what will be learned in coming years or what benefits will be forthcoming, but history has demonstrated repeatedly that no line of research fails to add ultimately to human welfare.

Moreover, the space sciences may in time answer philosophical questions that have intrigued the minds of men for centuries.

Is there life elsewhere than on earth?

What is the nature of the relationship of the earth to the moon, the planets, the sun, and the universe?

What can be learned about the origin of the universe?

Scope of geophysical investigations

Geophysical investigations by satellites and sounding rockets embrace an array of sciences and penetrate space extending thousands of miles from the earth. NASA's geophysical program concentrates largely on studying the atmosphere, ionosphere, energetic particles, and magnetic and electric fields.

THE ATMOSPHERE

NASA is investigating the properties and phenomena of the atmosphere from the altitude ceiling of balloons (about 20 miles) to regions of space beyond the last traces of atmosphere. The object is to determine the composition of the constituent gases and the structure (pressure, density, and temperatures) of the atmosphere, and to find how these properties vary from day to night and from season to season at different altitudes and geographical locations. Closely related work is going forward on (1) upper atmospheric winds and their circulation patterns, (2) studies of solar activities to correlate them with general atmospheric behavior, and (3) studies to learn how this complex of interrelations affects meteorological processes.

Atmospheric structure satellite

Instruments for this 400-pound satellite have been selected, and design and development are under way at Goddard Space Flight Center. Taking part, under NASA contracts, are the Consolidated Systems Corp., Monrovia, Calif.; NRC Equipment Corp., Newton, Mass., a subsidiary of National Research Corp.; and the National Research Corp., Cambridge, Mass. The satellite will be launched by a Delta vehicle.

Sounding rocket activities

Three Nike-Asp sounding rockets for determining upper atmosphere winds were launched from Wallops Station on November 18, 19, and 20. (See ch. 3, "Experimental Missions," p. 23.)

NASA plans to launch about 20 more sounding rockets for upper atmosphere studies. Half of the launchings will be for determining temperatures and winds at altitudes of from 20 to 50 miles. This will be done by exploding special grenades high in the atmosphere and then measuring the speed of the sound waves to calculate the temperatures and winds through which the waves pass. The program is under Goddard direction, with participation by the University of Michigan, the University of New Mexico, and the Schellinger Research Institute of Texas Western College.

The remaining rockets will be launched for other investigations of the upper atmosphere—for instance, determination of wind speeds and diffusion by employing sodium vapor released high in the atmosphere and for studies by means of mass and ion spectrometers and density and pressure gages. The sodium vapor experiments are conducted by the Geophysics Corp. of America under NASA contracts; Goddard will perform the other experiments. Some of the experiments will also test instrumentation for the atmospheric structure satellite.

Theoretical and experimental activities of NASA are being augmented, under contracts, by work of the Geophysics Corp. of America, the University of Michigan, and the Armour Research Foundation.

THE IONOSPHERE

NASA is investigating the origin and variations of the components of the ionosphere, the reasons for their variations, and their gross properties.

The ionosphere is a region of electrically charged (ionized) gases, beginning about 35 miles above the surface of the earth. Maximum ionization occurs at about 180 miles. The region includes a number of zones of somewhat different characteristics (called the D, E, F₁, and F₂ layers) that vary in altitude and ionization with the time of day and the season.

This ionization is believed to be caused principally by ultraviolet rays, X-rays, and charged particles streaming from the sun. Long-range radio communications are possible because the electrons of the ionosphere reflect radio waves of low and medium frequency back to earth.

Among instruments used to determine the numbers and properties of the gases, ions, and electrons are ion and mass spectrometers, radio-frequency impedance probes, and Langmuir probes.¹² Radio-fre-

¹² Instruments; not to be confused with space probes.

quency propagation experiments (detailed studies of the way radio waves travel through the ionosphere) of different types are also used. For example, a very low frequency experiment was carried in Explorer VI. Other experiments depend on detailed analysis of how the ionosphere affects signals from satellites or space probes.

Direct ionospheric measurement by satellite

Several satellites will be launched with the major objective of directly studying the ionosphere, which is of tremendous importance to radio communications on earth. The program will be under the project management of Goddard. The Marshall Space Flight Center, Huntsville, Ala., is responsible for assembling and testing the payload. A prototype of the instrumentation for the payload has been submitted for tests to the Marshall Center by Goddard Center. Two more payloads for flight testing are being assembled.

Ionosphere beacon satellite

Planned to follow the ionospheric measurement experiments is a satellite which will gather information about electron distribution and characteristics of the ionosphere by studying its effects on radio transmission. The payload will include electronic equipment for the simultaneous transmission of six harmonically related radio signals. Depending on their frequencies, these signals will be affected to varying degrees during their travels through the ionospheric region. Analysis of the signals will yield information about the structure and properties of the region. Goddard is managing the project and Marshall is designing, assembling, and testing the payload. Other participants include the University of Auckland, New Zealand, the University of Illinois, Pennsylvania State University, Stanford University, and the National Bureau of Standards.

Topside sounder

After the ionosphere beacon satellite experiments are completed, a third satellite, the Topside Sounder, will be employed to study the upper ionosphere by radio-echo sounding, a technique, similar to radar, used for years to study the lower portions of the ionosphere. The nature of the ionosphere makes it impossible to obtain information about the upper region from the ground because radar pulses penetrate the region and continue on into space instead of reflecting back to earth. The Topside Sounder will be the first attempt to apply radio-echo sounding of the ionosphere's top surface from above. In this joint Canada-United States program, the payload is being funded and built by the Canadian Defence Research Telecommunications Laboratory.

Electron Density Probes

Planned for future launching by Scout vehicles these two experiments will obtain vertical pictures of the structure of the ionosphere from a low altitude to one of 6,000 miles or more. Probe trajectories, rather than satellite orbits, will be used for measuring this altitude range in a short interval of time. Payloads are being constructed by Goddard and the vehicles are part of a developmental series of eight in the Scout project being directed by Langley Research Center.

As a preliminary to these probes, an Aerobee-Hi sounding rocket was successful on March 16. It reached an altitude of more than

200 miles. Payload instrumentation worked well, as did telemetry. The data are now being analyzed. The launching was part of activities being carried out, under NASA research contracts, by the University of Michigan and the U.S. Army Ballistic Research Laboratory. Other preliminary activities include several sounding rockets that will carry experiments designed by Goddard, the University of Michigan, and the Geophysics Corp. of America. Vehicle procurement and payload work are on schedule.

ENERGETIC PARTICLES

Radiation satellite experiments

The radiation belt satellite schedule for March 23, 1960, was to be an important step in this field. However, the launching was unsuccessful. (See "Experimental Missions," p. 22.)

Two such satellites are planned for 1961. Launched by Delta vehicles, they will have heavier payloads than did the 1960 radiation belt satellite. In addition to energetic particle detectors of the type built for the 1960 satellite, each of the 1961 satellites will also carry a magnetometer. Thus, it will be possible simultaneously to measure and correlate the magnetic field and the radiation in its vicinity. Magnetometer development is well under way, as is the selection of photocells for the optical-sensor system that will be installed to keep ground stations informed on the satellite's orientation. The project is under Goddard management.

Sounding rocket activities

Under this program, 10 sounding rockets will be launched to investigate neutron intensities, cosmic rays, and solar particles.

Project NERV (nuclear emulsion recovery vehicle), managed by Goddard, is included in this group of studies. The project involves launching and recovering small instrumented payloads after flights to altitudes as high as 1,300 miles into the radiation region. NERV will measure the radiation region more comprehensively than is possible at present.

Bell-shaped, the payload is 18 inches long and 19 inches in diameter and contains special photographic emulsion that is highly sensitive to nuclear radiation. Tracks left in the emulsion will reveal the levels of energies and types of radiation encountered.

Because the data contained in the emulsion tracks cannot be telemetered, NERV must be recovered. Hence, it is built to withstand severe landing shocks, and to float after it lands in the ocean.

On March 2, NASA completed prelaunch tests of the 75-pound NERV vehicle. The tests included (1) laboratory simulations of entry into the atmosphere, and (2) drop-recovery tests in the field.

The heat and buffeting of entry were simulated in the Malta, N.Y., laboratory of the contractor, General Electric Co. In the recovery tests, an F-104 Starfighter aircraft dropped the vehicle from an altitude of 7 miles over the Pacific Missile Range, near San Nicholas Island, Calif. All elements of the NERV recovery system operated as planned, including parachutes, search beacon, flashing light, radar chaff (confettilike stripes of aluminum foil—highly reflective to radar impulses—that will be ejected to aid in tracking the vehicle), and dye

marker to stain the sea, so that surface vessels may readily locate and recover the NERV payload.

Neutron intensity experiments are being carried out by New York University under a NASA research grant. These experiments will be flown later this year in an Aerobee-Hi sounding rocket.

Project SBE (solar beam experiments), another in the energetic particles sounding rocket series, consists of launching several small two-stage rockets. Several of them will be held ready to fire and will be launched shortly after a large flare on the sun has been detected. They will be used to study the nature, number, and velocity distribution of solar particles ejected by the flare. Data from this experiment will be particularly important both to our understanding of solar processes and to our ability to design proper shielding for manned space flight through and beyond the radiation zones.

MAGNETIC AND ELECTRIC FIELDS

Knowledge of the magnetic field of the earth at high altitudes and in space is necessary for detailed studies of ionospheric and auroral phenomena, and for studies of energetic particles and phenomena of the radiation region. Measurements of the strength and direction of the magnetic field at these altitudes are made by magnetometers carried by satellites and sounding rockets.

Of key importance to the program was Vanguard III (launched September 18, 1959) which made possible extensive mapping of a large part of the near-earth portion of the earth's magnetic field. Preliminary results of Vanguard III data were noted earlier. The satellite produced quantities of information; analysis will continue for months to come.

Early lunar and planetary probes will be equipped with magnetometers to obtain a knowledge of the magnetic fields of the moon, the planets, and of intervening space. Magnetometers, being developed at Goddard, will also be part of the instrumentation of some of the satellites launched for investigation of the earth's ionosphere and other geophysical phenomena.

NASA has scheduled six rocket launchings from Wallops Station to measure the earth's magnetic field and to investigate fluctuations that may be caused by electrical currents in the ionosphere. Four of the rockets will be instrumented by the University of New Hampshire. Two will test magnetometers for use in a lunar probe experiment.

ASTRONOMY

PROGRAM SCOPE

Scientific areas that NASA is investigating under its astronomy program include galactic astronomy and solar physics including gamma ray astronomy; relativity investigations; and radio astronomy. (For detailed description, see NASA's "Second Semiannual Report to Congress" Apr. 1-Sept. 30, 1959.)

During this period, work went forward on four satellites, an accompanying sounding rocket program, related theoretical and laboratory studies, and instrument development and design.

GAMMA RAY ASTRONOMY SATELLITE

This satellite is being developed to investigate gamma rays—high energy radiation of extremely short wavelength associated with the interaction of cosmic rays or other energetic particles with matter. The satellite will be equipped with instruments to detect and map extraterrestrial gamma rays in space (that is, gamma radiation originating from unknown sources in space), and to measure gamma ray phenomena associated with the earth's atmosphere.

GAMMA RAY TELESCOPE

The basic design of a telescope, specially designed to measure gamma rays, and to determine the regions of the sky from which the radiation comes, was completed by the Massachusetts Institute of Technology. A prototype model was delivered to the Marshall Space Flight Center for assembly with the satellite housing, telemetry equipment, and solar-cell power supply. Heat, electrical, and mechanical tests of the prototype payload are scheduled to begin in June.

The satellite is under the technical management of Goddard Space Flight Center. Plans call for use of a Juno II launch vehicle.

SOLAR SPECTROSCOPY SATELLITES

Work is in progress on two solar spectroscopy satellites which will measure the electromagnetic radiation from the sun in the ultraviolet, X-ray, and gamma ray regions of the spectrum and will study time variations of these emissions. In "visible light" spectroscopy, light is separated into its individual component colors or wavelengths. This is called a spectrum. Study of a spectrum provides detailed information about the composition and properties of the source emitting the light.

The solar spectroscopy experiments will be used to study some of the invisible light emitted by the sun. The satellites will be the first capable of performing intensive investigations of these solar radiations which are absorbed by the earth's atmosphere and hence cannot be studied from the ground.

Neutron monitor experiments, prepared by the Lawrence Radiation Laboratory, will also be carried out. The experiments will employ detector arrangements capable of counting neutrons in the presence of other energetic particles. The objectives are to determine whether particles in the radiation zone originate from the decay of neutrons and whether these neutrons come from the earth or from the sun or other sources.

Construction of the satellite structure and the flight-pointing control system is underway. An operating model of the pointing control that will keep the payload instruments trained on the sun was completed by Ball Bros. Research Corp., Boulder, Colo., and has met all test requirements. Design of the payload electronics system was completed in February 1960, when the need for greater reliability dictated that two separate data-handling systems should be installed. If one malfunctions, the other can be commanded to take over. The satellite will be launched by a Delta vehicle.

ORBITING ASTRONOMICAL OBSERVATORY

Objective of the fourth satellite under the astronomy program is to study the stars, sun, nebulae, and planets by means of a telescope mounted on an unmanned satellite that will orbit the earth well beyond the atmosphere. Above the absorbing and interfering effects of the earth's gaseous envelope, the observatory may help solve many of the mysteries of the universe, its composition and origin, that are hidden from us today.

Before the orbiting observatory is feasible, many intricate problems must be solved. For example, means must be assured to stabilize the satellite so that the telescope can be pointed accurately toward the planets in our solar system and toward the stars. To accomplish this, precision control of a degree never before attempted in a satellite must be attained.

Work in progress

Contracts have been let to several universities for preliminary studies and experiments. NASA's Ames Research Center has made engineering studies and worked on specifications for the stabilization equipment. In December 1959, a briefing on this project for interested members of industry was held at NASA headquarters and attended by some 150 persons. Purpose was to provide further information on requirements and planning to companies which have shown an earlier interest in the project.

In February 1960, the detailed technical management responsibility for the Orbiting Astronomical Observatory was assigned to Goddard.

Work is continuing on the specifications for the stabilized platform.

In March 1960, specifications were reviewed and discussed with the members of the NASA working group for this project. When the specifications are completed, proposals for engineering design and fabrication will be requested from industrial sources.

Sounding rockets will be used

About a dozen sounding rockets for the astronomy program are scheduled for experiments between April and October 1960. Designed and built by Goddard, the payloads will include experiments for solar spectroscopy and for detection of areas of ultraviolet emission in space.

SUPPORTING AND RELATED ACTIVITIES

Participating in the astronomy project, the University of Michigan has been studying low-frequency, cosmic background radio noise. Also closely related is work being done by the Canadian Defence Telecommunications Board in the previously noted cooperative Top-side Sounder program.

Under the Relativity Investigation Project, NASA contracts are in effect with the National Bureau of Standards and Hughes Aircraft Co. for the development of very accurate atomic clocks or frequency standards with very long stability or accuracy. The Massachusetts Institute of Technology is developing specialized electronic circuits and techniques for an experiment to test Einstein's theory of relativity through use of satellites. Detailed planning for such a satellite test by a study of the gravitational red shift effect must await the outcome of the ground-based tests now being conducted by a new

technique in several laboratories. However, as the accurate frequency standards will have many other uses in space technology, the clock development phase of this program will be continued.

Supporting theoretical, experimental, and instrumentation studies for the astronomy program are being conducted at Goddard, and by industrial organizations and universities under NASA contracts (listed in appendixes L and M).

THEORETICAL WORK

Research undertaken by the Theoretical Division of Goddard includes a program in celestial mechanics. Results under the program were touched upon earlier in this chapter. In addition, a special method for rapid determination of satellite orbits from radar data has been developed.

Studies are being pursued and new theories are being developed to describe lunar properties and motion. The work is a necessary prelude to space probe and satellite investigations of the moon. Goddard is developing a theoretical research program keyed particularly to the data on ultraviolet spectra expected to be obtained from the orbiting astronomical observatory.

CHAPTER 7

SATELLITE APPLICATIONS

SIGNIFICANT PROGRESS MADE

NASA is bringing substantial effort to bear on the development of special satellites to advance the technologies of weather forecasting and teleradio communications. It is in practical fields such as these that the information drawn from scientific space missions can now be utilized to greatest advantage.

Within the next decade, satellites should be in routine service to furnish meteorological observations on a global scale so that all the interdependent phenomena of weather in the making can be quickly sifted, analyzed, and understood on a scope impossible today. As meteorologists gain better insight into how the complex factors fit together, vastly improved and longer-range weather prediction will follow.

In the communications field, early NASA work is directed toward developing techniques from which will evolve a world-wide teleradio system. At this stage, activities are centered on fairly simple devices to test equipment and principles.

METEOROLOGICAL SATELLITE PROGRAMS

In October 1959, Explorer VII placed in earth orbit equipment to measure and transmit much information on the phenomena that make up weather. (See ch. 3, "Experimental Missions," pp. 9-14.) Although the satellite was not designed specifically for such observations, Explorer VII carried an experiment to determine how much heat the earth receives from the sun and how much is radiated back into space. Data are still being collected and interpreted.

During this period, a large effort was devoted to fabricating and testing TIROS I (orbiting on April 1) and to organizing means for acquiring and interpreting data from the satellite. (See ch. 3, "Experimental Missions," pp. 17-21.)

As preparations for launching TIROS went on, plans were maturing for its sequel, a family of satellites called Nimbus. All Nimbus satellites will have the same basic structure and components—such as telemetry, stabilizing equipment, etc.—along with provisions for installing improved or new instrumentation. Nimbus will be launched into polar orbit and oriented to face the earth at all times; it can thus view the entire globe and provide far more weather information than is possible with TIROS.

According to current plans, TIROS II will be launched late in 1960 and TIROS IIa during the first half of 1961. About 6 months later, Nimbus I will be launched, followed by Nimbus II in 1962 and Nimbus III in 1963. TIROS launchings will use the Delta vehicle, and Nimbus the Thor-Agena B.

COMMUNICATIONS SATELLITE

Project Echo

NASA's effort in the communications field has been concentrated largely on Project Echo, an experimental communications satellite program. In Project Echo, 100-foot diameter inflatable spheres composed of microthin aluminized polymer plastic to reflect electromagnetic (radio) waves, will be fired into 1,000-mile altitude orbits. Operational communications satellites will be injected into equatorial orbits at an altitude of 22,300 miles. Project Echo is designed to (1) study the effects of space conditions on satellites with large surface areas per unit weight; (2) measure reflectivity of the spheres and the manner in which radio waves travel through and are affected by space; and (3) determine the feasibility of using such satellites as radiowave reflectors in worldwide communications systems.

Management responsibility.—Overall management of Project Echo is by NASA's Goddard Space Flight Center. Langley Research Center is developing payloads. The communications experiments are being carried out by the Jet Propulsion Laboratory at its Goldstone, Calif., station and by the Bell Telephone Laboratories, Holmdel, N.J. The Naval Research Laboratory will participate from its Stump Neck, Md., site.

The Army, the Air Force, and seven educational and industrial institutions have volunteered to perform independent experiments. Other organizations have made inquiries.

In England, the Jodrell Bank facility of the University of Manchester will attempt to receive transmission from Holmdel. Scientists from several other countries have indicated to NASA that they will make use of Project Echo for experiments.

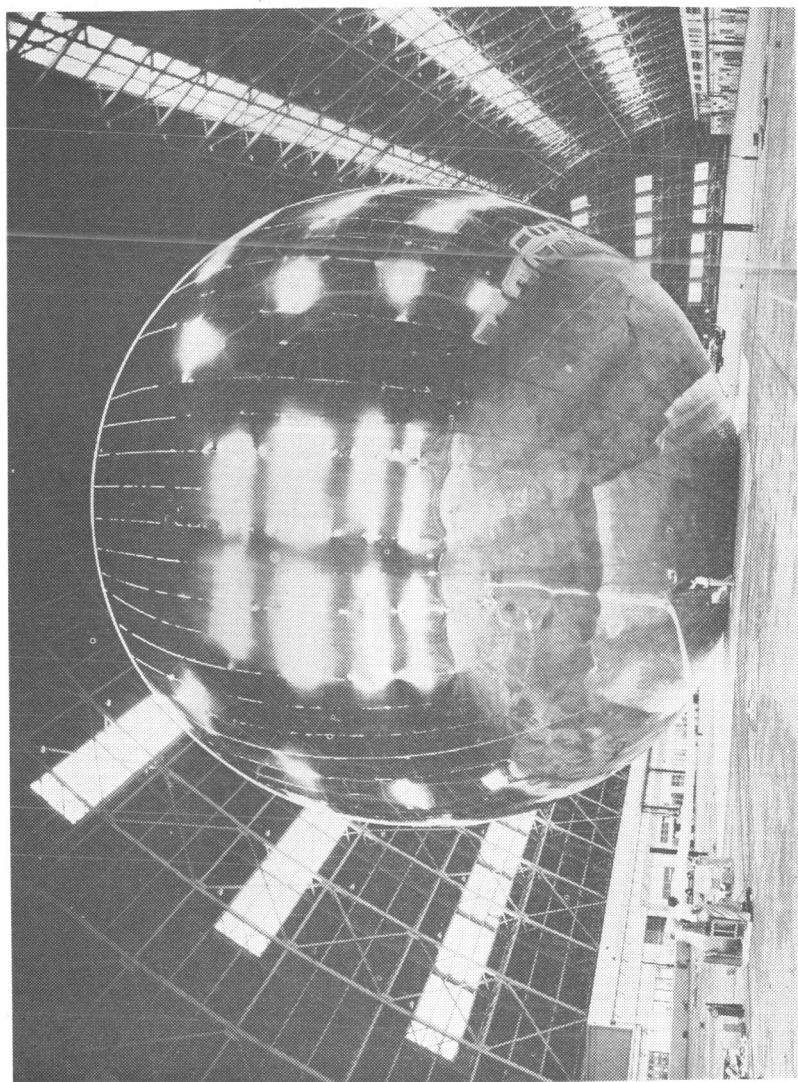
Payload.—Payload testing and development for Echo launchings is complete—including sphere design and fabrication, reflectivity measurements, inflation and folding techniques, container design and payload-vehicle compatibility.

The payload is a folded sphere of 0.0005-inch thick aluminized polymer plastic. Inflated, the sphere is 100 feet in diameter and has a volume of about 500,000 cubic feet.

The metal container for the folded sphere consists of two hemispherical parts laced together. In space, the plastic sphere will be ejected by a small exploding charge between the flanges of the hemispheres and under the lacing. The force of the charge will cut the lacing and force the hemispheres apart.

Before the sphere is launched, most of the air and water vapor in the folds are evacuated through the plastic skin by means of 243 tiny holes. The total hole area is about three-quarters of a square inch, which is less than the area of perforations expected during 1 day's exposure to micrometeoroid penetrations in space. Once in the near-vacuum of space, however, the traces of air remaining in the sphere expand greatly and inflate it to its 10-story diameter. The pressure is sustained by the action of 30 pounds of sublimating powder (benzoic acid, which in space becomes gaseous) sprinkled inside the sphere before sealing.

In a 41-foot-diameter vacuum chamber at Langley, scale models of the sphere have been tested extensively to find the best fabrication methods and techniques for separating the container and for ejecting



Project Echo 100-foot-diameter inflatable sphere is test-inflated. The sphere will be used in communications satellite experiments.

and inflating the plastic sphere. Two separation and initial (partial) inflation tests with a full-size 100-foot sphere were also made in the chamber.

Project Echo schedule.—The first Echo launching was scheduled for May 1960.¹³ Other launchings are planned for the third quarter of 1960 and for 1961.

Suborbital tests.—Along with the vacuum-chamber tests, suborbital tests of the Echo payload and of the third-stage Delta vehicle were made by Langley technicians at Wallops Station.

The Echo vehicle, assembled specifically for the tests, consists of a Sergeant first-stage—assisted by two Recruit rockets at liftoff—and an X-248 rocket engine as second stage (the X-248 comprises the third stage of the Delta). During the period, there were also four suborbital Echo launchings.

First sphere ruptures.—In the first suborbital test, liftoff came at 5:40 p.m. eastern standard time, October 28, 1959. The vehicle performed well, but the sphere ruptured when it was ejected from the container and inflated. Several fragments separated from the main body and continued along the ballistic trajectory, rising to an altitude of about 250 miles and entering the atmosphere some 500 miles down-range, east of Wallops. The sphere was visible along the Eastern seaboard. Even though the plastic ruptured, reflected signals from the DAMP radar of the Radio Corp. of America, at Moorestown, N.J., were received at Wallops.

Among probable causes for the sphere's rupture are: (1) concentrated stresses in the folded plastic, or (2) explosion of one of the bottles containing water used in this experiment to inflate the sphere. (Stresses in the skin of the sphere have been redistributed and lessened by employing a new folding technique. Water-inflation has been discarded in favor of benzoic acid sublimating powders, as earlier noted.)

Second suborbital test.—The second test was made from Wallops on January 16, at 5:35 p.m. eastern standard time. At an altitude of 250 miles, a short circuit in the launch vehicle second stage prevented firing of the de-spin rockets, and of the retrorockets which slow the second stage to prevent collision with the inflated sphere. The X-248 engine ripped through the partially inflated sphere, releasing the benzoic acid gas.

Despite this accident, a Bell Telephone Laboratory transmitter at Holmdel, N.J., reflected a radio signal off the sphere to receivers at the General Electric Laboratories, Schenectady, N.Y., and to the Massachusetts Institute of Technology's Lincoln Laboratory, Round Hill, Mass. Because inflation had been incomplete, the signals were below expected strength.

Third test—Voice transmitted via sphere.—The third suborbital experiment was launched at 6:20 p.m. eastern standard time, February 27, from Wallops Station. The payload was identical with that of the second test, except that a red fluorescent powder was used as part of the sublimating material. Also, the electrical system of the vehicle had been changed to prevent repetition of the previous failure. As the sphere proceeded along its trajectory, a red glow appeared to its left. Undoubtedly red fluorescent powder blown through a hole in

¹³ Failed May 13.

the skin accounted for the glow. What caused the hole is not known, but measures have been taken to reduce internal pressure in the folded sphere to slow initial expansion.

Despite the inflation failure, the Bell Laboratories transmitted a taped voice message of 12 sentences via the sphere to the General Electric and Lincoln Laboratories stations. Volume of the message was only slightly below the planned level.

April test succeeds.—NASA achieved its first completely successful launching, ejection, and inflation of a 100-foot-diameter inflatable sphere in a suborbital trajectory on April 1. Ejection and inflation took place at an altitude of 100 miles. The sphere was fired by a two-stage launch vehicle, consisting of a Sergeant rocket and two Recruit rockets as first stage, and an X-248 engine as second stage. The sphere, inflated by sublimation of benzoic acid, was visible as a star-like object along the Eastern seaboard, from Maine to South Carolina, and 500 miles inland from Wallops Station.

Volunteer participation.—Photographic coverage for the suborbital tests, in addition to that by NASA facilities, was provided by participants in the volunteer satellite tracking program. Radar tracking for the first two tests was by the Radio Corp. of America, Moorestown, N.J. The Millstone Hill radar of the MIT Lincoln Laboratory and U.S. Navy radar picket ships tracked the second and third spheres, and the U.S. Air Force provided aerial observation.

Echo ground facilities

A 10-kilowatt transmitter and receivers with extremely sensitive, low-noise amplifiers have been installed for use in communications experiments at the JPL Goldstone Station. For sending, these experiments will employ the new AZ-E1 parabolic antenna that can be rotated either up and down or left and right, independently. For receiving, the 85-foot equatorially mounted antenna will be used. This antenna is mounted in the manner of an astronomical telescope so that it can easily be turned to correct for the earth's rotation.

At Holmdel, N.J., the Bell Telephone Laboratories are assembling for NASA, under contract, ground equipment developed at their own expense. Of note are a new type of receiving antenna with a 20- by 20-foot receiving area, especially built to reduce noise; low-noise receivers employing dual masers (very sensitive amplifiers); and a 10-kilowatt transmitter. The transmitting antenna has a diameter of 60 feet.

In testing the equipment, one-way, moon-bounce experiments were made from Holmdel to Goldstone. The Holmdel equipment was also used for the suborbital tests.

For the orbital Echo experiment, Goldstone will transmit to Holmdel at a frequency of 2390 megacycles and will receive the Holmdel transmission at 960 megacycles.

CHAPTER 8

LUNAR, PLANETARY, AND INTERPLANETARY PROGRAMS

SPACE EXPLORATION: SECOND PHASE

Although less than 3 years have passed since the era of space flight opened, satellites and probes of a number of types have been sent far into the immensities of the solar system to explore routes which human beings may eventually follow. Some of these devices have circled the earth as satellites, others have sped to the moon or beyond, and three space probes have swept into orbits around the sun at planetary distances.

Fruits of early space missions are serving NASA as the basis for the second phase—an orderly evolution of launching vehicles, scientific payloads, and spacecraft leading to unmanned investigations of the Moon, Venus, and Mars in preparation for manned expeditions. For the sake of completeness, a brief statement of programs planned, on most of which preliminary work has begun, is included in this report.

THE PROSPECT

For the coming 5 to 7 years, NASA has selected goals that appear entirely practicable and has assigned them the following order:

- Interplanetary probe.

- Lunar orbiters.

- Lunar impacts (high-resolution TV during approach plus survivable capsule).

- Planetary probes to Mars and Venus.

- Lunar soft landings.

- Planetary orbiters to Mars and Venus.

- Lunar soft landings with mobile vehicle.

The years immediately beyond 1965 will be devoted to improvement and use of spacecraft for missions with Saturn.

SCIENTIFIC GOALS

From the viewpoint of science, the missions projected are as exciting as will be the drama of the flights themselves. The scientific objectives are:

To acquire fundamental physical and chemical information on the moon and planets; to investigate space phenomena and their variations over the range of lunar and planetary distances; to explore the surface and nearby environment of the moon and to measure and describe in detail its characteristics, for example, the surface composition, radioactivity and structural features, and the magnetic and gravitational fields; to investigate the constituents, processes, and characteristics of the interplanetary re-

gions so as to understand how and why they vary with time and location within the solar system; to extend these investigations to the detailed study and exploration of the planets; to develop improved means and techniques for the conduct of lunar, interplanetary and planetary investigations and explorations.

The nearest and most familiar body to us in the solar system is the moon. Clear, dry, and apparently changeless, the moon has been an object of speculation for thousands of years. Devoid of atmosphere in the terrestrial sense, the moon has had no winds, no rains, no chemical interactions for billions of years to alter its surface. It offers a chance to study the very early matter of the solar system in practically unchanged form.

Until recently, lunar science had to rely entirely on telescopic observations and indirect measurements. Spacecraft now being developed will overcome many of these limitations. By providing means for orbiting or landing on the moon instruments capable of directly gathering and transmitting information back to earth, lunar missions will greatly increase understanding of the universe. It is certain that they will answer many insistent scientific questions.

Planetary investigations will study still more interesting problems. Associated with the lunar, planetary, and interplanetary programs is the search for extraterrestrial life forms. Since the existence (or non-existence) of such life forms is unknown at this time it is vitally important that the biological balance, such as it may exist, of celestial bodies not be disturbed by contamination with terrestrial microorganisms. Similarly, great care must be exercised not to disrupt the ecology on earth when in future years, extraterrestrial samples are returned. In recognition of this problem, NASA is currently embarking on a program which will lead to a method, procedures, and techniques for the decontamination and sterilization of space probes and payloads.

Just as the lunar missions constitute an orderly sequence of technological and scientific development, so do they lay the groundwork for more distant and complex missions of the 1965-70 period.

SCHEDULE CRITERIA

Mission schedules have been developed to—

- (1) Select the most important goals and pursue them with determination.
- (2) Establish an evolutionary sequence of missions in which each step paves the way for the more difficult phase to follow and makes full use of increased technological capability.

LUNAR MISSIONS

NASA plans call for eventually making controlled landings on the moon—first, by scientific devices to sample radiation and other phenomena and, later, by manned spacecraft.

FIRST STEP: INSTRUMENTED LUNAR ORBITERS

NASA will make at least two attempts to place an instrumented payload in orbit about the moon. An Atlas-Able launching vehicle will be employed.

The lunar orbiters will utilize a spin-stabilized payload having rudimentary, but effective, midcourse guidance—without which the mission could not be accomplished. The payloads will contain several radiation detection experiments to take measurements in the lunar environment. As “anchored” space stations, unaffected by terrestrial influences, the payloads should yield quantities of important scientific information when the long-term measurements they make are compared with related measurements taken in the vicinity of the earth.

SECOND STEP: CONTROLLED LANDINGS ON THE MOON

In 1961, NASA will begin the next phase of the lunar program. Spacecraft designed for controlled landings will be launched by Agena B vehicles. The payloads will bear special sampling and transmitting equipment rugged enough to survive the landings in working order. The two payloads launched in the first half of 1961 will be directed, not toward the moon, but into highly eccentric earth orbits that will reach far out toward the sun. They will be employed to test vital components of the spacecraft and to make scientific experiments.

A “spacecraft,” as meant here, is an advanced vehicle that will not only carry a payload of scientific instruments but will be capable of maneuvering to maintain the correct course and orientation, through built-in programming equipment and by means of remote command-control from earth stations.

In early space-mission experiments, the payload and telemetry equipment were packaged in what were little more than cans, spin-stabilized in flight or allowed to tumble at random. Soft-landing lunar spacecraft of coming years will be far more complex. They must descend to the surface of the moon without the cushioning, or “braking” effects of an atmosphere. They will have to land by means of rocket-braking and will be guided and controlled by on-board electronic sensing equipment.

LUNAR IMPACT MISSIONS

Early in 1962 the first of three attempts at complete lunar missions will be ready for launching. The spacecraft will be in two sections, the spacecraft “bus” and the landing capsule. The bus will contain guidance and control, telemetry, and propulsion equipment to maintain vehicle attitude during the entire trajectory and to make it possible to strike the moon in a predetermined area. The payload capsule will be separated from the bus and slowed by a retrorocket from about 8,000 feet per second to an impact velocity of less than 500 feet per second.

In addition to scientific instruments for measurements of space between the earth and the moon, the spacecraft will be equipped with a television camera that, during the final moments of flight, transmits pictures of the impact area. The camera will be capable of recognizably photographing objects as small as 10 feet across.

SOFT LANDINGS

In 1963 the powerful Centaur should be operational, making possible the first true lunar "soft" landing of a spacecraft equipped with television, a seismograph, a spectrometer, and radiation detection devices among other relatively fragile scientific instruments to observe and analyze the surface and subsurface properties of the moon. Telemetry and an electric power supply will make up part of the 600-pound package.

Television inspection of the terrain obtained in the preceding Agena series will aid in designing the landing structure of the Centaur spacecraft. It is likely that the Centaur type will be used for years in lunar exploration.

Still larger, soft-landing spacecraft, boosted by the Saturn 1.5-million-pound-thrust launch vehicle, will be required for areas of the moon that are to be investigated in great detail, either for purely scientific reasons or in preparation for manned landings. Planned for 1966, with a 3- to 4-year leadtime for development, the Saturn-launched, unmanned spacecraft will contain a unit that can move along the moon's surface—perhaps on caterpillar treads or balloon tires. Television will play a key role in this kind of remotely controlled exploration.

PLANETARY AND INTERPLANETARY MISSIONS

During 1960, a Delta will be employed to launch a probe deep into interplanetary space to measure magnetic, particle, and electromagnetic radiation fields. In 1962, NASA should be capable of placing probes in the vicinity of Venus. For such a mission, NASA will employ the Centaur launch vehicle, and a variation of the spacecraft scheduled for the Atlas-Agena lunar missions. These probes will pass close enough to the planet to permit critical scientific measurements to be made and transmitted back to earth. Television and/or spectrographic observations are being considered. These "near miss" flights are difficult to achieve, however, because of the extreme accuracies required in the guidance system as well as present uncertainties in the position of the planets.

The relative position of Earth and Venus required for near optimum payload weights will occur in 1964. During that year, NASA will probably attempt a Venus probe to test stellar-navigation equipment for use aboard the Venus orbiting spacecraft scheduled for launching by the Saturn in 1965. These spacecraft will weigh several thousand pounds and will eject instrumented capsules to penetrate the atmosphere of the two planets and gather scientific data.

CHAPTER 9

INTERNATIONAL PROGRAMS

TRACKING NETWORK NEGOTIATIONS

NASA, through the Department of State, concluded agreements for establishing and operating Project Mercury tracking stations in Australia and in Spain's Canary Islands on February 26 and March 19, respectively. The Australian agreement also provided for the renewal of Minitrack and Baker-Nunn station arrangements and for establishing a deep-space station.

The existing Minitrack agreement with Ecuador has been renewed for five years, beginning February 24, 1960. Negotiations for five other Mercury stations, an additional Deep-Space station, and two Minitrack stations are continuing. (See ch. 10, "Tracking and Data Acquisition," pp. 73-79.)

COOPERATION IN SPACE RESEARCH

DISCUSSIONS WITH SOVIET SCIENTISTS

In November 1959, the possibility of cooperative space efforts was discussed with Soviet scientists attending the American Rocket Society meeting in Washington, D.C. The response indicated prospects of a step-by-step effort to develop cooperation. The first step would involve participating in a United Nations space conference which was originally proposed by the Soviet U.N. delegation.

TRACKING SERVICES OFFERED SOVIET UNION

On December 7, 1959, the Administrator, speaking for NASA, offered tracking services -subject to the consent of the host countries - to the Soviet Union for any manned space flight program it may develop. NASA also offered to provide equipment or to use equipment furnished by Soviet scientists if special recording or data reduction facilities should be required.

DISSEMINATION OF TECHNICAL INFORMATION

Advance technical information on the Project Echo experiment, to study the possibilities of communicating by means of ultra-high-frequency radio signals reflected from a satellite, was disseminated to the world scientific community. This gave scientists everywhere an opportunity to prepare the necessary equipment and arrange for such ground-based experiments as appeared feasible. Similarly, NASA notified the international scientific community that telemetry calibrations for Explorer VII would be available to them for direct reduction of the data received from the satellite.

COOPERATIVE SPACE PROGRAMS

Possibilities of cooperative space programs were discussed with several countries during the period.

Australia

The Australian Academy of Science proposed the preparation of instrumentation to study very-low-frequency emissions along lines of magnetic force above the ionosphere. The instrumentation would be part of some future U.S. rocket and/or satellite experiments. Informal discussions regarding a possible joint sounding rocket program were also held.

United Kingdom and Canada

Cooperative programs with the United Kingdom and Canada progressed. The experiments to be conducted by means of the first United Kingdom satellite to be launched by NASA were agreed upon. Joint working groups were established for both United Kingdom and Canadian satellite projects. As a result of another arrangement with the Canadians, a project to study signals received from earth satellites is being conducted at Baker Lake in Northwest Territory, Canada. Funded by NASA, the project is conducted by the University of Illinois.

Japan

Following both informal and diplomatic communications and an invitation from NASA, a team of Japanese scientists visited NASA headquarters in mid-February for informal technical discussions looking toward a cooperative program. Formal arrangements for cooperative space research programs are anticipated at some time in the future.

Other

Discussions with several additional countries expressing interest in cooperative efforts were in preliminary stages.

FIRST INTERNATIONAL SPACE SCIENCE SYMPOSIUM

NASA representatives gave extensive support to the National Academy of Sciences delegation to the meeting and First International Space Science Symposium of the International Committee on Space Research (COSPAR), in Nice, France, January 8–16, 1960. NASA's offer to fly foreign experiments in American rockets and satellites was reaffirmed.

GRANTS TO FOREIGN SCIENTISTS

Several grants were made to foreign scientists under a NASA-sponsored postdoctoral resident research associateship program administered by the National Academy of Sciences. These are for basic space-connected research in the United States and afford recipients an opportunity to take part in and contribute to NASA's scientific programs.

INTERNATIONAL COOPERATION THROUGH THE UNITED NATIONS

BACKGROUND

On February 5, 1959, the Secretary of State named NASA Deputy Administrator Hugh L. Dryden as an alternate U.S. representative (to Henry Cabot Lodge) to the United Nations Ad Hoc Committee on the Peaceful Uses of Outer Space, established the previous year. This committee began discussions early in May 1959 and reported to the General Assembly on July 14 (in U.N. Document A-4141).

PERMANENT U.N. COMMITTEE ON PEACEFUL USES OF OUTER SPACE
ESTABLISHED

On December 12, 1959, the United Nations General Assembly (by unanimous resolution [1472 (XIV)])—

1. Established a (permanent) Committee on Peaceful Uses of Outer Space with membership from Albania, Argentina, Australia, Austria, Belgium, Brazil, Bulgaria, Canada, Czechoslovakia, France, Hungary, India, Iran, Italy, Japan, Lebanon, Mexico, Poland, Rumania, Sweden, Union of Soviet Socialist Republics, United Arab Republic, United Kingdom, and United States of America.

2. Requested the committee—

(a.) To review, as appropriate, the area of international cooperation, and study practical and feasible means for giving effect to programs in the peaceful uses of outer space which could appropriately be undertaken under United Nations auspices, including:

(1) Assistance for the continuation on a permanent basis of the research on outer space carried on within the framework of the International Geophysical Year;

(2) Organization of the mutual exchange and dissemination of information on outer space research;

(3) Encouragement of national programs for study of outer space, and the rendering of all possible assistance and help in their realization; and

(b.) To study the nature of legal problems which may arise from the exploration of outer space.

3. Requested the committee to submit reports of its activities to subsequent sessions of the General Assembly of the United Nations.

4. Decided, in view of the great progress in and importance of this field of endeavor, to convene, in 1960 or 1961, under the auspices of the United Nations, an international scientific conference of the interested members of the United Nations and members of specialized agencies, for the exchange of experience in the peaceful uses of outer space.

5. Requested the Committee on Peaceful Uses of Outer Space, established by the resolution, to work out proposals in regard to the convening of such a conference.

NASA PREPARES FOR CONFERENCE PARTICIPATION

In agreement with the desire of the Department of State, NASA undertook to prepare for U.S. participation in the Conference. To effect this, NASA established the Office for the United Nations Conference on January 29, 1960, under the Office of the Deputy Administrator. Dr. John P. Hagen was assigned as its Director.

CHAPTER 10

TRACKING AND DATA ACQUISITION

ROLE IN SPACE PROGRAM

Man's early successes in space exploration are due in no small part to development of intricate ground equipment to locate and track satellites, probes, and rockets, to receive their signals and reduce them to intelligible form, and to correlate the information so that it can be analyzed and applied to a multiplicity of purposes. These functions are performed for NASA by its tracking and data acquisition networks.

GENERAL OBJECTIVES AND DESCRIPTION

Ground tracking and data acquisition networks must be capable of supporting four basic types of operational missions: (1) vertically fired sounding or research rockets; (2) earth satellites; (3) manned earth satellites which will require extremely rapid data-gathering techniques to permit continual monitoring of the safety of occupants; and (4) deep space probes which require communications over vast reaches of space. Ground instrumentation must answer the questions: Where is the spacecraft? What is it doing? What information is it acquiring? What instructions must be radioed to the spacecraft so that it can perform its mission?

In addition to tracking and data acquisition equipment, the network must have a communications system that permits rapid data transmission to a central control point. At the control center there must be high-speed computing equipment to reduce the data to a form useful to experimenters.

MINITRACK NETWORK

DESCRIPTION AND OPERATION

The 10-station Minitrack network tracks and gathers data from earth satellites. During this period, the Minitrack network acquired information transmitted by Vanguard I, Vanguard III, Explorer VI, and Explorer VII. Contact was still maintained with Vanguard I and Explorer VII as the report period closed.

The 10th Minitrack station, located at Fort Myers, Fla., became fully operational early in December. Other stations are at Blossom Point, Md.; Antigua, West Indies Federation; San Diego, Calif.; Quito, Ecuador; Lima, Peru; Antofagasta and Santiago, Chile; Woomera, Australia; and Esselen Park, Union of South Africa. The stations are linked to a communications and control center at Goddard Space Flight Center, Greenbelt, Md.

NETWORK BEING EXTENDED

To extend high-latitude coverage, NASA is planning to establish stations at Fairbanks, Alaska; East Grand Forks, Minn.; and with the permission and cooperation of the governments concerned, at St. John's, Newfoundland, Canada; and Winkfield, England.

EQUIPMENT IMPROVEMENT

New receiver

NASA has let a contract to Bendix Aviation Corp. for an improved telemetry receiver. It will enable present electronic tracking stations to receive and interpret an augmented variety of radio signals from spacecraft, particularly the complex data from future meteorological and astronomical satellites.

Automatic data read-out system in test

A prototype of a new automatic data read-out system is being tested at NASA's Blossom Point, Md., station. The system, which permits transmission of digital tracking data directly from a tracking station to the control center, will increase station capabilities for tracking and data collection by 50 percent without additional personnel. It will also speed up data processing, since it eliminates manual reading at stations.

Self-tracking telemetry antenna being developed

NASA has awarded a contract to D. S. Kennedy & Co., Cohasset, Mass., for development of a self-tracking telemetry antenna. The new antenna will operate automatically (antennas at some stations now require attendants) reducing personnel requirements and increasing efficiency in data gathering.

NASA considering photoelectric equipment

NASA is planning to negotiate a contract for development of photoelectric optical tracking equipment. The equipment will trace objects in space by an electronic system which detects optical signals too faint to be recorded by photographic emulsions. NASA will first supply the technology involved to develop a photoelectric telescope to check the accuracy of Minitrack electronic devices more precisely than present telescope equipment. Photoelectric tracking will be superior to present photograph systems because it is more sensitive and can provide data instantaneously.

CONVERSION OF TRACKING FREQUENCIES

The first set of antennas with the newly assigned 136-megacycle and 137-megacycle frequencies have been installed at the Blossom Point station. Conversion of the Minitrack network to these frequencies, which were allocated to the United States by the International Telecommunications Union Conference, is scheduled for completion in December 1960. They will replace the 108-megacycle frequency originally assigned for the International Geophysical Year.

OPTICAL TRACKING

DESCRIPTION

Baker-Nunn network

The system comprises a worldwide network of 12 stations. The chief equipment at each station is a nonmobile camera capable of photographing a faint object (13th magnitude) against a star background. Baker-Nunn cameras are particularly valuable for determining the initial trajectories of satellites and space probes and for providing precise information on space vehicles needed for air-density and geodetic studies. Illustrative of the capabilities of the Baker-Nunn system are its photographs of Vanguard I at an altitude of 2,500 miles and of Explorer VI at 12,000 miles. Vanguard I is 6.4 inches in diameter, and Explorer VI is 39 inches in diameter.

Locations

There are Baker-Nunn stations at Hobe Sound, Fla.; Curacao, Netherland West Indies; Arequipa, Peru; Villa Dolores, Argentina; Olifantsfontein, Union of South Africa; Cadiz, Spain; Shiraz, Iran; Naini-Tal, India; Woomera, Australia; Mitaka, Japan; Haleakala, Hawaii; and White Sands, N. Mex.

Moonwatch stations

Moonwatch observers are volunteer teams using relatively simple telescopic equipment. They serve in numerous capacities, for example, sighting satellites to help aim the big Baker-Nunn cameras, and discovering new objects in the skies. Moonwatch stations are located at approximately 200 sites throughout the free world.

Technical direction and control

NASA's optical tracking systems are under technical direction of the Smithsonian Astrophysical Observatory. The central control point is at the Smithsonian Astrophysical Observatory Center, Cambridge, Mass.

OPERATIONS

Help identify "unknown" satellite

Moonwatch observations in Australia and South Africa and a Baker-Nunn observation in South Africa were instrumental in determining that the unknown satellite first reported on February 16, 1960, was actually the data capsule from Discoverer V, an Air Force satellite.

Increasing equipment capabilities

New equipment, improved methods, and added personnel have made it possible to increase the development and interpretation of Baker-Nunn camera observations from an average of 60 to more than 400 per month. Split-second timing is necessary to gain the greatest value from precision photographs. The Smithsonian Astrophysical Observatory is studying techniques for improving timing.

DEEP SPACE NETWORK

Description

NASA's Deep Space tracking network consists of one existing station at Goldstone, Calif., a station under construction at Woomera, Australia, and a third planned for South Africa. Capabilities of these stations closely approach those of the theoretically ideal deep space network which would be located on the equator at intervals of 120° of longitude. Primary objective of the network would be to maintain contact with space vehicles on lunar and interplanetary missions. The stations require giant antennas, sensitive receiving equipment, and high-powered transmitters. NASA is selecting valley sites so that the terrain will obstruct manmade electrical interference that might limit station sensitivity. The control center for the Deep Space network is at the NASA Jet Propulsion Laboratory, Pasadena, Calif.

Goldstone transmitter completed

In March 1960, NASA completed the transmitting system for the Goldstone station. The transmitter and receiver were located 7 miles apart to minimize electrical interference with each other. The sites are linked by a wide-band (10-megacycle) microwave communications system, which transmits pointing data, computations, tracking data, etc., between stations.

ADVANCED TECHNICAL PROGRAMS

Extensive research and development is in progress at the Jet Propulsion Laboratory and at Goldstone in preparation for communications satellites such as Project Echo and for other advanced communications experiments. The passive communications satellite concept has been tested successfully by radio voice communication via the Moon between Goldstone and the Bell Telephone Laboratory station, Holmdel, N.J. Scientists at JPL and Goldstone are developing more sensitive receivers and designing antennas larger than those currently used. Such equipment is a prerequisite for future lunar and interplanetary exploration programs.

MERCURY NETWORK

OBJECTIVES

The worldwide Mercury network will provide complete radio tracking, voice communication, and data acquisition during launching, flight, and recovery of the Mercury capsule. The network will be capable of more detailed data gathering and faster tracking than the Minitrack network. Emphasis, as in the entire Mercury program, is on assuring the astronauts' safety (see ch. 5, "Manned Flight in Space and Near-Space," pp. 36-48.)

PROGRESS

Projected locations

Mercury stations are planned at the following locations: Cape Canaveral; an island in the Atlantic Ocean; the Canary Islands; southwest and southeast Africa; Woomera and Perth, Australia; an island in the Pacific; White Sands, N. Mex.; Point Arguello, Calif.;

Corpus Christi, Tex.; Valparaiso, Fla.; Guaymas, Mexico; and on two ships—one in the Indian Ocean and the other in the mid-Atlantic Ocean. The Mercury control center will be consolidated with the Minitrack control center at Goddard Space Flight Center.

Construction

Construction of radio equipment and support structures (buildings, etc.) are in progress at all new sites; none of the new stations had become fully operational by the end of this period.

Negotiations

Negotiations and technical arrangements for Mercury station sites abroad were nearly complete on March 31 (see ch. 9, "International Programs," p. 70).

Wallops Station, Va.

COMPLETE LOCAL TRACKING AND TELEMETRY SYSTEM

Wallops Station, comprising facilities on Wallops Island and the inactivated Chincoteague Naval Air Station on the mainland, is a unique launching facility—one with a complete tracking and data collection system. Wallops instrumentation enables the gathering of data for research in aerodynamics and for the development and proof testing of various components and techniques to be used in launching space vehicles from major ranges such as the Atlantic Missile Range and the Pacific Missile Range.

MAJOR PROJECTS

Principal experiments conducted during the period included launchings of (1) "Little Joe" to test the Mercury escape system under high dynamic pressure; (2) the 100-foot diameter inflatable sphere in preparation for the Project Echo experiment; (3) six-stage rockets for entry physics studies; (4) Javelin rockets to gain information on the performance of the Delta launch vehicle third stage; (5) the Scout launch vehicle to test its destruct system; and (6) sounding rockets for upper atmosphere research (Aerobee rockets for NASA, Strongarm rockets for the Army Ballistic Research Laboratory and the University of Michigan, and ARCAS rockets for the Army Signal Corps).

ADDITIONAL TRACKING EQUIPMENT INSTALLED

Tracking and data collection facilities installed during the period included command destruct equipment; one mobile and one fixed telemetering station; and a building, a tower, and a 60-foot antenna for the S-band radar (for range safety and position information) on the mainland. The latter device will increase the range of tracking of any Wallops vehicle by several fold.

COOPERATING STATIONS

SUPPLEMENT CURRENT CAPABILITIES

NASA utilizes the tracking facilities of other organizations to supplement its networks. For example, the Jodrell Bank radio telescope at Manchester, England, has a key role in the Pioneer V probe experi-

ment. It will maintain contact with the solar orbiting probe long after it is out of range of other stations.

Phototrack stations

Phototrack stations, administered by the Society of Photographic Engineers, have optically tracked the 100-foot inflatable spheres launched from Wallops Station, Va., in preparation for the Project Echo experiments in communications by relay of ultra-high-frequency signals from a satellite. NASA has obtained valuable data on sphere inflation from the society's photographs.

Telemetry stations

Telemetry stations in Japan and West Germany, and of the U.S. Weather Bureau in this country have assisted in gathering data from Explorer VII.

OVERALL DEVELOPMENTS

CONSOLIDATION OF GROUND COMMUNICATIONS

Data from the various stations are transmitted to central control points by a ground communications web consisting of military and leased commercial lines. Wherever possible, lines are used in common. NASA has begun a long-range study looking toward eventual consolidation of ground communications into one worldwide system.

NEW FREQUENCY ASSIGNMENTS

A number of radio frequency bands for space science uses were allocated the United States at the International Telecommunications Union Conference. The conference was held between August and December 1959 at Geneva, Switzerland, with NASA representatives in attendance. NASA has applied for several of the bands to the Interdepartmental Radio Advisory Committee, Office of Civil Defense Mobilization, which is the national coordinating agency for frequencies used in space activities. NASA has been using frequencies loaned by other U.S. agencies. It is now converting to a new Minitrack frequency and plans conversion of the Deep Space network to higher frequency bands.

COMPUTATION AND DATA REDUCTION

Consolidation of data reduction and computation

Goddard Space Flight Center is consolidating data reduction and computation so that information from satellites can be interpreted rapidly and efficiently.

Preparations for transfer from IBM

Goddard is preparing programs for the IBM-709 and IBM-7090 computing machines to be installed at its Greenbelt site. Plans have been made to effect as smooth a transition as possible when control center functions are transferred to Goddard from the IBM Space Computing Center in Washington, D.C.

Research Aids

Goddard also utilized computers to support NASA research activities. These are primarily broad programs of research in all phases of theoretical physics and applied mathematics relevant to space exploration. Large-scale computer operations were carried out on a contractual basis. Industrial and Governmental machines in the Washington, D.C., area are employed.

Mercury network

Plans were made to modify and develop procedures which will meet the ultra-high-speed computation standards needed for Project Mercury.

CHAPTER 11

PROPULSION AND NUCLEAR ENERGY APPLICATIONS FOR SPACE

SPACE PROPULSION

Demand for rocket engines with ever higher thrust has intensified research on new and improved fuels. In NASA's research centers, the quest goes on for powerful energy sources to propel supersonic aircraft and coming generations of spacecraft. Chemical rockets continue to receive strong attention since they appear to offer immediate benefits. Beyond chemical rockets—whose limitations are predictable—are other sources of power for exploring the reaches of interplanetary space. Nuclear energy has great promise, as does solar heat, collected in umbrellalike structures pointed at our primary source of energy, the sun.

TYPES OF RESEARCH FACILITIES USED

Facilities at NASA's research centers are being used in many different aspects of propulsion research. Static tests of rocket engines employ simple stands on which the engines can be fastened down and run under the atmospheric pressures and temperatures encountered near sea level. For advanced tests, more elaborate test stands support engines with as much as 20,000 pounds of thrust while they are run under closely controlled conditions in which pressures and temperatures can be varied to simulate different altitudes or the near-vacuum and extreme cold of space. For example, a method for altitude simulation has been perfected at the Lewis Research Center that employs the exhaust gases of the rocket engine to deplete the air in a capsule surrounding the engine itself, thus reducing pressure at the nozzle exit.

Work is in progress at Lewis to design and build an electrically heated wind tunnel that will supply air at a temperature of 15,000° F., for studying heat transfer in vehicles entering the atmosphere. The tunnel will also be used to investigate the effects of magnetic and electric fields on ionized gases. The chief difficulty lies in the employment of an electric arc for heating without contaminating the air with material from the melting electrodes. A small tunnel has been operated successfully, and a larger one is being designed.

CHEMICAL ROCKETS

In evaluating performance of a rocket propellant, one generally accepted criterion is "specific impulse"—that is, the number of seconds one pound of propellant mass will produce one pound of thrust. (A simple analogy might be the "miles per gallon" of an automobile.) Of today's chemical propellants, liquid hydrogen is one of the most promising. It has high specific impulse,¹⁴ far higher than that of

¹⁴ In combination with an oxidizer or when heated in a nuclear reactor.

kerosene, which is at present the basic ingredient of our most used rocket fuel. Kerosene, with liquid oxygen (LOX) as the oxidizer needed for combustion, has a specific impulse of between 290 and 310 seconds. In comparison, that of liquid hydrogen-LOX is 400+ seconds. This higher specific impulse is more important than might be inferred, for the propulsive energy of a given rocket system when all these factors are constant increases with the square of the specific impulse. Thus, hydrogen's ability to boost a payload is nearly twice that of kerosene's.

FUEL-OXIDIZER RESEARCH

In this area, a perennial difficulty has been the chemical reactivity (incompatibility) of many of the potential fuels and oxidizers when used in combination. In theory, the best chemical oxidizer is ozone, a form of oxygen that contains three oxygen atoms per molecule instead of two as in the conventional form of oxygen. But ozone is extremely unstable, and is prone to explode spontaneously. Fluorine, another highly active oxidizer, also produces a higher specific thrust with hydrogen than does oxygen, but it is violently corrosive to metals and known plastics, particularly at high temperatures.

Studies at Lewis Research Center are directed toward learning ways to handle, contain, and store fuel-oxidizer combinations safely and reliably. For example, plastics and metals are exposed to fluorine at high temperatures to determine the chemical reactions that take place, and attempts are being made to synthesize plastics (called "fluorinated polymers") of higher chemical resistance.

The rates at which liquid hydrazine, still another type of chemical fuel, "dissociates," or breaks down, when exposed to high temperatures have been measured, and the results indicate that the explosions that sometimes occur with this propellant probably originate in gas bubbles that are formed during the decomposition process.

Research is also being conducted on a method for igniting solid propellants, using reactive liquid oxidizers. The objective is to learn how pressure, composition of the solid propellant, and other variables affect ignition.

HYDROGEN-FLUORINE ENGINE

NASA has extended its contract with Bell Aircraft Corp., Niagara Falls, N.Y., for development of a liquid fluorine-liquid hydrogen rocket engine. The engine is now in the "breadboard" or laboratory (workable but nonflyable) stage.

As previously explained, the combination of liquid fluorine and liquid hydrogen has the highest theoretical performance of any bi-propellant systems for rocket engines,¹⁵ but is extremely reactive and toxic, and therefore imposes handling problems for rocket use.

PHYSICS AND CHEMISTRY OF COMBUSTION

Current NASA research on rocket combustion has two major objectives: (1) To learn how and at what rate the fuel-oxidizer combination reacts to form the hot gases that produce thrust; and (2) to learn how pressure pulses or surges occur and what controls their magnitude.

¹⁵ Except the hydrogen-ozone combination mentioned above.

A better knowledge of how fuels burn in a rocket can simplify development of new engines and help reduce development time and cost. Knowledge about combustion pressure pulses will give the key to controlling unstable burning, which would, in turn, lead to far more reliable operation of rocket engines.

A mathematical method has been developed at Lewis for relating the shape and size of the chamber—and other factors such as pressure, temperature, velocity, etc.—to the rate at which propellant drops evaporate in it. Work so far has shown that the mathematical concept applies to many propellant systems. A technique has also been devised to follow the atomizing process and subsequent evaporation in the combustor.

Results obtained cannot at present be applied to propellants that ignite spontaneously when the components are mixed. However, further research is being conducted on mixing and reaction processes of such fuels, and it now appears that a mathematical model applying more generally to rocket combustion can be achieved.

Pulsating or unstable combustion can destroy a rocket engine. NASA research has already disclosed methods for reducing or eliminating pulsations; however, the goal is a rocket engine in which pulsations could not occur in the first place. Accordingly, NASA is seeking a better understanding of combustion vibrations or surges.

Recent studies have given a clearer picture of the way shock waves break up liquid jets, and have determined the critical conditions that can cause such breakup and the sudden increase in combustion rate that follows. Other experiments have shown that a flame, suddenly accelerated can generate a pressure pulse. Still other studies, experimental and theoretical, are now underway to examine how pressure pulses affect the rate that fuel drops evaporate and the rate at which heat is transferred to surrounding walls. From these studies may also come knowledge of the factors that control the size to which the pressure waves can grow.

In the design of upper-stage rocket systems using low pressures in the pilot feed (analogous to the pilot light on a gas stove) and pressure chamber, two problems are particularly critical. The first is to devise a control system for maintaining stable propellant flow; the second, to eliminate low-frequency combustion oscillations.

To obtain design criteria for effective control of flow systems, techniques were developed to measure the dynamic characteristics—that is, the fast-changing events as they are taking place—of representative combustion chambers. Using hydrogen-oxygen thrust chambers of several different configurations or shapes, initial measurements were made of the timelag before combustion took place, and the oscillations and pressure surges that occurred.

Similar work was started to study the combustion characteristics of hydrogen-fluorine rocket engines operating at low chamber and injection pressures. A study of several propellant injection methods using different ratios of fuel to oxidant at pressures ranging from 20 to 60 pounds per square inch (p.s.i.) has been started in a simple (sea level atmospheric pressure) test stand. Preliminary results indicate that with a chamber pressure of 60 p.s.i., a "showerhead" injector yielded high combustion efficiency at the higher mixture ratio. With lower mixture ratios, however, efficiencies decreased.

ROCKET-ENGINE EXHAUST NOZZLES

The design of the nozzle through which the hot gases from a rocket engine are exhausted to produce thrust is a very important factor in the overall efficiency of the engine. Most nozzles now in use are cone-shaped or bell-shaped. Experiments are in progress to determine not only the most efficient shapes and nozzle-area ratios but also the lightest overall configurations. The nozzle area ratio is the relative size (in cross section) of the end of the nozzle, or exit, and the throat, or narrowest part. The shape of many commonly used nozzles is somewhat analogous to that of the bowl of a burgundy glass flaring out from a comparatively narrow throat.

Factors being considered include the effect of exhaust pressure, the losses from heat and from aerodynamic eddies or currents, the weights of the nozzle, and, of course, its shape. The object is to keep the design simple and the length short without sacrificing performance. Short nozzles simplify engine gimbaling (swiveling on a flexible mount to change the direction of thrust); they also reduce weight and make upper stages more compact.

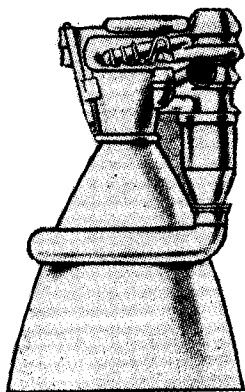
An investigation of rocket nozzles of very high area ratio, for upper-stage rockets and space vehicles, is being conducted in the Lewis 10- by 10-foot supersonic tunnel. The program has included tests of both conical and bell-shaped nozzles, the former primarily for reference data. The bell shapes are believed to be more practical configurations from the viewpoint of overall vehicle performance (in which thrust gains must be measured against weight increases). The General Electric Co. is participating in the program and supplying the bell-shaped nozzles in area ratios of 25 to 1 and 200 to 1. Results show a 15-percent increase in thrust from an 8-to-1 conic nozzle to a 200-to-1 bell-shaped nozzle.

"PLUG NOZZLE" FOR ROCKET ENGINES

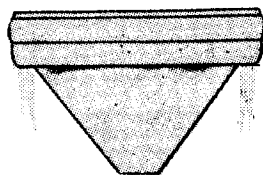
Through the General Electric Co., as contractor, NASA has been investigating the "plug nozzle" concept for rocket engines. The work is going forward at GE's Malta test station, Schenectady, N.Y. In this concept, the rocket exhaust gases, instead of flaring out from a bell-shaped vent, push into the atmosphere or space from what is almost a reverse configuration. That is, the exhaust streams out from combustors that are arranged in segments around a central inverted cone, or plug. The plug deflects the hot gases issuing from the combustors and permits the out portion or perimeter of the gases to expand, unconfined. At all altitudes below the ideal design altitude, such an engine will theoretically perform better than a conventional engine. Use of small segmented chambers, instead of the much larger chambers of conventional rockets, gives an additional advantage—the individual combustor units can be arranged in suitable numbers to produce engines of various sizes or thrusts.

An initial experimental investigation of the plug nozzle rocket engine was completed by GE in January 1960. Tests started with rectangular injectors in uncooled combustors. Later, double-walled, cooled combustors were used, so that longer tests could be run. The first series of tests provided data for designing an injector that produced stable combustion. The later tests with cooled chambers

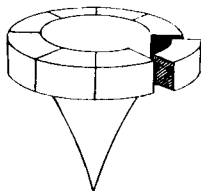
indicated a high level of rocket performance, with heating rates of metal components held to levels comparable with those of conventional engines.



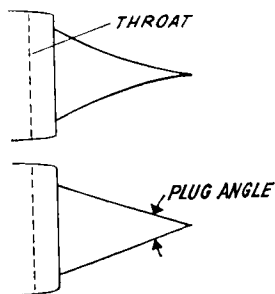
Conventional Rocket Nozzle



Plug Nozzle



Segmented Combustion Chamber
Design for
Plug Nozzles



Two Basic Plug Shapes
Isentropic or "Loss Free" (Upper)
Conical (Lower)

Another portion of the test program was devoted to investigating aerodynamic performance of the plug nozzle. Results indicated that a truncated form of the plug, making the nozzle much shorter, performed almost as well as the longer, theoretically more efficient,

shape. Tests also showed that the plug nozzle is well adopted to steering: by throttling the pressure of the gases issuing over one side of the plug, it is possible to change or displace the line along which the thrust force acts.

A study was also completed that furnished information for design-future plug nozzle engines over a wide range of conditions and sizes.

After completing the first phase of this program, General Electric submitted a proposal to continue work to produce a flight version (50,000-pound thrust) of the plug nozzle engine. NASA has agreed to the proposal.

PROBLEMS IN PUMPING CRYOGENIC FLUIDS

When liquid hydrogen and LOX are pumped from their storage tanks and forced through lines and valves to the combustion chamber of a rocket engine, these cryogenic (extremely cold) fluids present special problems not common to ordinary liquids like water.

One of these problems is cavitation, the formation of vapor-filled bubbles in the liquid. Cavitation usually occurs on the suction side of pumps, reducing their efficiency and reliability. The theoretical mechanics of cavitation are not quantitatively understood even in common liquids such as water, and for cryogenic liquids research data are limited.

Work has been started at Lewis on a systematic program to investigate the dynamic effects of cavitation. A small return-flow cryogenic liquid tunnel is being assembled, with which it is planned to obtain data using various cryogenic liquids (including liquid oxygen, nitrogen, and hydrogen) over a wide range of pressures and flow velocities.

High-speed photographs have shown that there is a fundamental change in the nature of pump cavitation in liquid hydrogen, the vapor being rather uniformly dispersed as very fine bubbles throughout the liquid. Tests have indicated that liquid hydrogen pumps can be designed so that mechanical damage does not occur, and good performance can be maintained even when the hydrogen is boiling.

Still another problem with all liquid propellants is that in the conditions of weightlessness in the space environment they may change to a physical state that is very unsatisfactory for passage through the pumps to a rocket engine. Under these conditions, the propellant may boil (hydrogen boils at -252.7°C ., oxygen at -183°C .) or become filled with bubbles of vapor or gases that could vapor lock the pump. Also, large slugs of vapor might be pumped instead of the required liquid.

STORAGE OF CRYOGENIC PROPELLANTS DURING SPACE MISSIONS

To take full advantage of the power of cryogenic propellants for missions to other planets, we must insulate and protect the fuels against heat to keep them from vaporizing and to prevent excessive losses. NASA has investigated techniques for providing such protection. Results indicate that by orienting the vehicle properly and using multiple layers of reflective metal foils, each thermally isolated from the next, propellant losses can be reduced to a fraction of one percent for trips to nearby planets such as Mars and Venus. Preliminary

studies indicate that adding thermal protection will have little adverse effect on vehicle design. Therefore, despite the extra "hardware" required to protect cryogenic propellants, most advantages associated with their high specific impulses can be retained for interplanetary missions.

GAS GENERATORS FOR TURBOPUMP SYSTEMS

The turbine that powers the pumps in a rocket system is usually driven by a high-energy gas source, which can be achieved most economically by burning the two propellants in a combustion chamber called a gas generator. The hot gas from the gas generator can be made to serve a second purpose: by adding a heat exchanger, the system can be used to pressurize and fill the void in the tanks as the propellants are consumed.

The operation, performance, and control of the gas generator is critical to the successful performance of the rocket vehicle. Accordingly, an experimental investigation of the gas generators using liquid hydrogen and LOX is in progress at Plum Brook.

TURBOPUMP SYSTEMS INVESTIGATIONS

The relation between the pumps and a complete high-energy rocket system is being analyzed at Lewis, to determine ways of improving both. A preliminary study was made to learn how much the performance of hydrogen-oxygen engines could be increased by using a "topping drive" turbine¹⁶ to power the pumps. Upper stage engine configurations of the type used in the Centaur rocket were considered. Results have indicated that the performance was only slightly higher than that attained with the bleed system. (In the bleed system only a small flow is required for the turbine and therefore little relative performance is lost.)

Turbopump designs for large hydrogen-oxygen engines were also studied. The engines considered were of the size and type that are to be employed in the advanced Saturn vehicles. Of particular concern was the effect that cavitation would have in limiting turbopump efficiency, and its interactions with tank pressure and tank pressurization systems, and tank weights.

In further experimental investigation of turbines for high-energy rocket systems, a cold-air model (using unheated air for the test rather than the actual fluid) of a two-stage unit was built to try out the "bleed system"—that is, employing a small percentage of the propellant to drive the turbine and then exhausting the spent propellant overboard. The major problem is to get enough power to drive the turbine properly without appreciably reducing the specific impulse. The results of this investigation indicated a total efficiency of approximately 46 percent for the turbine proper - relatively good performance for two stages.

A small three-stage unit is also being investigated as part of a general program for a turbopump in an engine with 20,000 pounds of thrust. A cold-air model achieved an efficiency of 53 percent. This unit will also be tested at high temperatures (about 1400°) in the pilot turbine facility at Plum Brook.

¹⁶ Somewhat analogous to the old-fashioned overshot waterwheel.

The conventional bleed system and a monopropellant drive system for use in this application were compared analytically. Results indicated that the bleed system required about one-third the flow rate of the monopropellant system (using hydrazine). The lower flow rate would permit lifting an increased payload on various types of missions, the amount of increase varying with the mission.

LIQUID HYDROGEN PRESSURIZATION STUDIES

In modern chemical rocket systems, gas pressure is used to force the liquid propellant into the pump and to provide sufficient head to keep the fluid from cavitating at the pump. An experimental and analytical study is underway to find out how much gas it takes to pressurize a hydrogen propellant tank and force the liquid hydrogen out. The program objective is to obtain basic information leading to the design of a pressurization system of minimum weight.

The experimental test rig for this program makes it possible to vary the amount of propellant sloshing, the temperature of pressurizing gas, the amount of heat leaking into the tank, and the rate at which the liquid flows out. The effect of all these variables on the amount of pressurizing gas required can then be measured.

Tests have been run using both hydrogen and helium as the pressurizing gas. With both gases, the major factor affecting the quantity needed was found to be the temperature of the tank walls; the less heat transfer to the walls, the greater the efficiency.

Further studies are being carried out with liquid hydrogen and liquid oxygen in a flow system that more closely simulates those used in flight, with propellant tanks, flow lines, flight controls, and related equipment. Initial results indicate that the liquid hydrogen—when pressurized to a prescribed value and then forced out of the tanks without any additional pressurizing gas—remains in the boiling liquid condition which is desired for maintenance of pressure.

SOLID-PROPELLANT ROCKETS

HIGH PERFORMANCE ROCKET MOTORS

During the period, two contracts for high-performance rocket motors let in 1959 were completed and another was extended. New contracts were signed for five more projects. Work authorized should be completed in 1960.

Upper stage rockets

Grand Central Rocket Co. of Redlands, Calif., is continuing work under its contract to develop an experimental rocket engine with a very high proportion of weight of propellant to that of inert parts. The two 500-pound engines thus far test-fired failed soon after ignition; these engines will be modified in an effort to correct deficiencies, then fired in further tests. Other phases of the program are being extended.

Negotiations are in progress on a contract to investigate the potential weight-saving capabilities of a nozzle cooled by liquid metal. The large heat-absorbing capacity of liquid metal may allow the use of very thin metal nozzle cones, if the liquid metal can be kept in uniform contact with the cone to absorb the heat generated by the exhaust gases. Calculations show that such a nozzle can be lighter in weight—

especially in the larger sizes—than one using current ablation¹⁷ materials such as polyethylene plastic.

A contract to investigate the combination of several modern design features in a single sounding rocket is being negotiated. Weighing about 200 pounds, such a rocket could be built to go 40 percent higher than present rockets without the need for developing a single new concept.

The performance potential of a rocket engine having no conventional nozzle will be investigated under a contract now being negotiated. Although not as efficient as nozzle units, the low weight, simplicity, reduced cost, and improved reliability may make this radically different design attractive for some applications.

The utilization of several concentric layers of different solid propellants to allow a simple internal shape, requiring almost no chamber insulation, will be evaluated. The test unit will weigh about 600 pounds and include a plastic chamber made in two halves. Contracting for this program was initiated in March 1960.

Negotiations are also in process on a contract to investigate the potential of end-burning propellant charges in upper-stage rockets of low weight. Because end-burning charges have no central perforation, all the chamber volume is used, giving added efficiency. They also allow more flexibility of rocket burning time.

LARGE BOOSTERS

Final reports were received on two 1959 contracts to determine potential advantages of large solid rockets as initial stages. The programs, conducted by the Lockheed Aircraft Corp. of Sunnyvale, Calif., and the Aeronutronic Division of the Ford Motor Co., showed that—on the basis of overall vehicle design—a solid fuel booster can be more efficient than a liquid booster. Solid units can readily be designed to deliver maximum thrust for a given total vehicle weight, while liquid rockets are more limited because of the size of the fuel-feeding machinery required. By developing a higher thrust-to-weight ratio, the solid unit attains full velocity more quickly, and minimizes velocity loss due to gravity. For a given total vehicle weight, it has also been found more efficient to use a solid booster, which, being smaller than the corresponding liquid booster, permits more weight to be concentrated in the upper stages.

STEERING AND VELOCITY CONTROL

During early 1960, NASA requested bids for designs and test of an experimental vehicle steering and velocity control unit. Of fourteen proposals received, two, representing different approaches, were chosen, each having advantages in different locations on a multistage vehicle. Negotiations with these contractors will be complete in the near future. These systems will be developed this year and adapted later to actual vehicle stages.

In March 1960 a contract was let to the Naval Ordnance Test Station, Inyokern, Calif., to study the feasibility of controlling the direction of thrust from a nozzle by injecting gas or liquid into the nozzle

¹⁷ A method of cooling in which a surface coating of material—for example, certain plastics—melts and vaporizes, protecting the surface beneath it.

expansion cone. This injection causes a shock wave to form in the cone, deflecting the main exhaust by several degrees. It should thus be possible to steer a vehicle by injecting on command at different cone locations. Although initial tests will be made with 500-pound rocket engines, this method may prove particularly useful in steering large initial stages requiring great forces.

THRUST MODULATION

At present, there is no efficient method of continuously controlling the thrust level of a solid-fuel rocket. In 1959, a contract was negotiated with Acoustica Associates, Inc., of Los Angeles, Calif., to determine if thrust could be varied by adding acoustical energy (sound waves) to the burning propellant surface. Combustion instability in solid rockets indicates that the burning rate can be radically affected by energy waves generated spontaneously in the combustion chamber. The Acoustica program is attempting to generate controlled energy by means of a siren or whistle and apply it to propellants burning under pressure.

A series of tests were made with propellant strands in a closed pressure vessel with no noticeable results. Later, small rocket engines were fired, in which an induced thrust level variation of about 10 percent was noted. The sonic source used was a highly efficient whistle that generates over 150 decibels in air at a frequency of about 10,000 cycles per second (cps). More test firings will be made after designs are changed to increase the effect on burning rate.

MATERIALS AND MANUFACTURING TECHNIQUES

Several factors could limit the use of solid-propellant rockets. For example, nozzle materials must resist temperatures of more than 6,000° F. (See ch. 12, "Materials and Structures," pp. 96-98). Also, if solid rockets are to be utilized as multi-hundred-thousand-pound boosters, new means of making them must be developed.

The contract initiated in 1959 with the Arde-Portland Corp., Newark, N.J., to study the properties of several materials suitable for constructing high temperature nozzles is still in progress. Metallic carbides and other substances to be evaluated have been difficult to fabricate in the size required, and only two test rocket firings have been carried out, one of which was simply to prove the equipment and instrumentation. In the second test, a nozzle throat section of high density metallic carbide withstood exhaust conditions considerably more severe than any produced in even the most advanced of present-day rockets. The theoretical temperature of the flame was 6,700° F. and during the 39-second burning time, the 3/4-inch-diameter throat increased only .04 inch.

ELECTRIC ROCKETS

Electric rocket-propulsion systems yield extremely weak thrust but can obtain almost unlimited jet velocities without consuming much propellant. For missions in space where gravity forces are small, they offer a number of advantages, since they are compact and can generate thrust for long periods of time. There are several types of electric rockets now under study by NASA. These include ion rockets,

plasma rockets, and electro-thermal rockets (discussed in more detail under individual headings below).

DEVELOPMENT OF ELECTRICAL PROPULSION SYSTEMS

Proposals have been requested from industry on competitive bids to develop a 30-kilowatt electrothermal arcjet for satellite propulsion, a 1-kilowatt arcjet for satellite stabilization, and a 30-kilowatt ion rocket for propulsion of interplanetary probes. Proposals for these projects have been received and are now being technically evaluated. Contracts will be awarded in the near future.

Future electrical propulsion development activities will include further support of these three development projects, together with supporting studies directed toward special problem areas such as power generation (for details see "SNAP-8 Development," p. 95).

Electric rocket test facilities

Since ion and plasma rockets can operate only in a near vacuum, test facilities for experimental research and development must be built so that virtually all air can be pumped out—down to about one-billionth of normal atmospheric pressure. The problem is made even more difficult because the facilities must continue to maintain these extremely low pressures even when an electric rocket engine under test is exhausting its propellant continuously into the test tank.

Three vacuum facilities of this type have become fully operational at NASA's Lewis Research Center since the last progress report, bringing the total to four. Experience with these devices, first of their kind in the United States, has been used as the basis for design of a much larger facility for developing full-scale electric rockets. Construction of the new facility will begin shortly.

Experimental research on electric rocket engine concepts has been greatly increased in recent months; at present four ion rocket engine designs are being investigated, a plasma rocket engine experiment is underway, and two electrothermal rocket engines are being developed by theoretical analysis and small-scale experiments. Analyses of interplanetary vehicle missions propelled by electric rockets are also continuing.

ION ROCKETS

Ion propulsion employs a propellant consisting of a stream of positively charged ions—that is, atoms which have been given a positive electrical charge by removing one electron from each. The alkaline element cesium is well suited as the basic propellant for such a system, since a cesium atom becomes ionized when it comes in contact with a hot surface of tungsten or rhenium. Known to science for almost half a century, this ionization method is 99 percent efficient, and is simple and readily adaptable to a light, compact design.

A stream of cesium ions can be shaped into a beam and accelerated in much the same way the cathode ray "gun" in a television picture tube shoots a beam of electrons to activate the luminescent screen. In space propulsion systems the beam of ions is emitted to produce thrust; the mass flow is extremely low, but the ion exhaust velocity can reach hundreds of miles per second. The final step, as the ions leave the rocket, is to reinject electrons to neutralize the charge.

This prevents a negative electrical charge from building up on the space vehicle. At the same time, it neutralizes the positive charge in the jet area, which would otherwise interfere with other positive ions moving out of the jet.

Experiments in progress at Lewis are evaluating four ion rocket engine designs based on widely differing concepts, and designed for missions ranging from correcting the orbits of communications satellites to supplying propulsion for interplanetary flight. In preliminary tests, fairly good power energies have been obtained (as high as 58 percent of the power theoretically possible), and with knowledge gained to date, it is expected that this efficiency can be greatly improved.

Many of the processes that take place in ion engines are being analyzed in detail, using the experimental engines and auxiliary apparatus. New instruments are being developed to permit acquisition of better and more complete data in the near future.

PLASMA ROCKETS

Plasma propulsion makes use of many of the same principles and techniques that are being studied in the search for controlled thermonuclear fusion. A plasma is a body of ionized gas (positive ions and negative electrons) at very high temperature. A plasma rocket differs from an ion rocket in that the ions and electrons are not separated and ejected in two separate beams, but are intermingled and ejected together in a common beam. Also, an ion beam is accelerated electrostatically, a plasma beam, electromagnetically.

Experimental results indicate that some plasma devices previously proposed have little promise for propulsion applications. Consequently, the plasma rocket research program has been realigned to place more emphasis on acceleration systems of demonstrated promise. The program also continues investigations of a few systems for which the limitations have not as yet been determined even approximately. One system of the latter variety involves accelerating a plasma by means of a magnetic field oscillating at radio frequencies (150 to 450 kc.). A critical experiment, using an accelerator designed for continuous operation, is underway in an effort to determine the potential of this type of device.

Other types of plasma accelerators are being evaluated, including capacitor-discharge devices that produce repeated pulses. Initial experiments indicate that velocities can be attained suitable for propulsion applications, but the acceleration force drops rapidly as the plasma flows away from its starting point. This requires that the system have a short "time constant"—in other words, the pulses must be repeated extremely rapidly, so that the energy stored in the capacitors will be quickly replaced and as quickly again discharged.

Work is also going forward on several plasma generation systems that would, in conjunction with a plasma accelerator, make up a complete engine.

ELECTROTHERMAL ROCKETS

Electrothermal rockets differ from ion and plasma rockets in that a propellant gas is heated electrically and permitted to expand through a nozzle to form a high velocity jet without being accelerated by external electric or magnetic fields.

Lewis is investigating several such devices, one of which uses an electric arc discharge to produce sudden heating of the propellant gas.

USE OF SOLAR RADIATION FOR PROPULSION

NASA is continuing its investigation of solar energy to heat hydrogen and thus produce rocket thrust. The study so far has shown that specific impulses from 900 to 1,500 seconds may be obtained in engines that can accelerate 0.3 foot per second. Such a system, applied to a manned Moon mission or Mars mission, might reduce weight of the upper stages enough to permit their use with a Saturn launch vehicle.

The chief problem is to cut down the weight of the solar collector to one-fortieth of a pound per square foot. This weight requirement appears possible to achieve.

NUCLEAR ENERGY APPLICATIONS FOR SPACE

Power from controlled nuclear fission, although first achieved in practical measure during the last decade, has now grown familiar and almost commonplace. Electricity produced by nuclear power reactors has been lighting homes and turning the wheels of industry in the United States and abroad for several years. But the application of this enormous, almost unlimited source of energy, to thrust-producing devices for driving launch vehicles and spacecraft on missions that are now impossible is a challenge to space scientists and rocket engineers.

NASA is in early stages of developing two types of nuclear systems for space propulsion: (1) nuclear heat transfer rockets, and (2) nuclear electric generating systems. The latter are intended to produce enough electricity to power an electric rocket engine (See "Electric Rockets," pp. 89-90).

NUCLEAR HEAT TRANSFER ROCKETS

The potential of the nuclear rocket lies in its high specific impulse. This far outstrips today's most powerful chemical rockets. The nuclear rocket will consist of the following basic components: (1) aellant tank, containing liquid hydrogen at approximately -430° F.; (2) a pump and its associated drive system, to force the liquid fuel to (3) a nuclear reactor which heats it and transforms it to hot gas; and (4) a nozzle through which the gas is expelled to provide thrust. Vehicle and mission studies are being conducted which indicate that comparatively small and simple nuclear rockets would be desirable for high energy missions.

The nuclear rocket program is a joint effort of NASA and the Atomic Energy Commission. NASA supports AEC's reactor test program by developing the non-nuclear components required, and supplying the necessary hydrogen propellants. Among these components are the hydrogen pump, turbine, and rocket nozzle. In proper time phase with AEC's reactor test program, after completion through a working model engine demonstration, NASA will have developed a flyable engine system integrated into a nuclear rocket vehicle. Most probable first application would be as a top stage of a chemical rocket

launch vehicle; the nuclear rockets would start to operate after having been launched by the chemical lower stages into an earth orbit.

Nozzle cooling problems

A high-temperature reactor is needed for an efficient nuclear rocket—the higher the temperature, the more thrust is obtained from the heated hydrogen propellant passing through the nozzle. However, the nozzle cooling problem, already difficult in chemical systems, is intensified. Several research programs are accordingly being conducted on nozzle cooling at the Lewis Research Center. A recently completed preliminary analysis indicates that wall temperatures higher than those generally used in nozzle design will almost undoubtedly have to be considered.

Data on heat transfer rates from hot gas to nozzle walls are being experimentally determined in several chemical rockets; correlations of these data should also be applicable to nuclear rockets. Data on rates of heat transfer from the nozzle wall are also being gathered, using an electrically heated tube through which the hydrogen coolant flows at ranges of pressures and temperatures comparable to those encountered in nuclear nozzles.

Pump and turbodrive systems

Like chemical rockets, large nuclear rockets will require a pump and turbodrive system to move the hydrogen fuel from the storage tanks to the reactor. Cavitation problems are similar to those mentioned for chemical rocket engines utilizing liquid hydrogen, except that additional difficulties are imposed by radiation heating. Axial (straight-through) flow, multistage pumps may be used to obtain the high pressures required, and systems of this type are under study.

Problems associated with turbine drive systems suitable to nuclear rocket applications are being investigated experimentally. The first system studied is of the bleed type in which a small fraction of the pump discharge bypasses the thrust chamber after some heating, and after expanding through the turbine is discharged overboard. The turbine, sized in the general range suitable for nuclear rockets of the Rover type discussed in previous reports, is a unit with eight full stages. The complete turbine is now being fabricated and is to be tested in the main turbine test facility at Plum Brook. The first two stages are already undergoing tests in the turbine pilot facility (a small-scale facility to guide the design and construction of the larger one mentioned above) at Plum Brook, using both hydrogen and nitrogen as the drive fluids. (An elaboration of these tests in various single-stage turbines has indicated that there is practically no difference in performance between hydrogen and nitrogen.)

Hydrogen turbopump systems

As discussed in the second semiannual report, NASA is developing a liquid hydrogen turbo pump feed system for the Rover reactor test program, and is supplying the hydrogen required in all testing related to the nuclear rocket program. Among flow system components involved is the liquid hydrogen pump (and a six-stage turbine to drive it), being developed under contract with the Rocketdyne Division of North American Aviation, Inc. Currently, test pumps are being tested under varied pressures and flow rates.

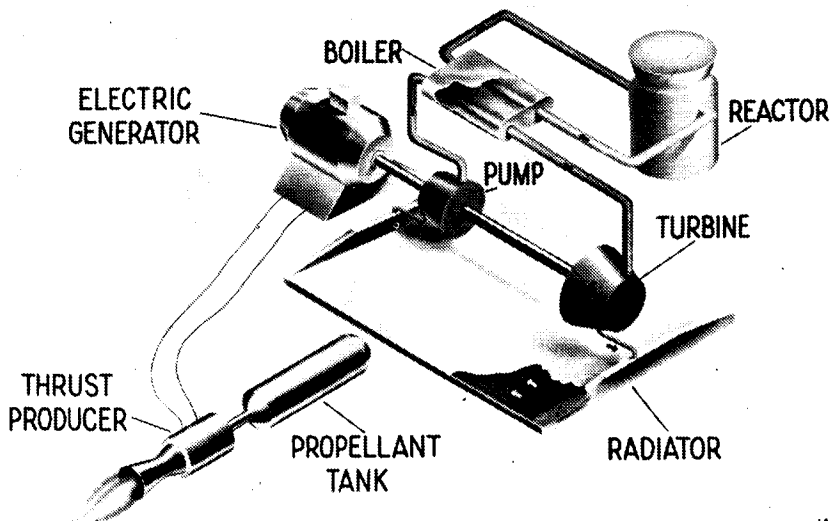
NASA is also investigating ways of controlling the flow systems of nuclear rockets. Under a contract with the Aerojet General Corp., Azusa, Calif., starting characteristics of such a system are being studied. Experimental work has been completed; analytical work is continuing.

Arrangements are in progress to support work at the National Bureau of Standards' Cryogenics Engineering Laboratory, Boulder, Colo., on the basic properties of hydrogen required for flow system design. Work will also include instrumentation required in hydrogen flow systems.

Reactor shielding

Analytical and experimental work at Lewis is aimed at devising more accurate methods of evaluating the shielding required to protect men and equipment from radiations emitted by nuclear reactor powerplants and from radiations in space. Any permissible reduction in weight of the shielding will reduce the propulsion effort of getting a vehicle into orbit; it is estimated that each pound of shielding may increase gross weight of the vehicle by 10 pounds.

NUCLEAR ELECTRIC PROPULSION SYSTEM



Basic components of proposed nuclear electric propulsion system for NASA satellites and probes.

The present analytical method of determining shielding requirements (based on an application of the "Monte Carlo" statistical method) is capable of accurate results but requires a large number of calculations. Work is in progress on techniques that will greatly reduce the number of calculations needed for adequate accuracy. Values established by both these methods and the "Monte Carlo"

technique are being checked against experiments conducted in a "swimming pool" test reactor using gamma-ray sources and various shield configurations.

NASA is negotiating a contract with the Technical Research Group, Inc., of Syosset, N.Y., for research and development of radiation shielding for space flight applications which holds promise of being lighter than conventional shielding. An analysis will be made of the use of a separated disk which will scatter radiation away from payload or crew compartments and out into space.

POWER GENERATION

SNAP-8 development

The SNAP-8 (system for nuclear auxiliary power) reactor holds promise for application to coming generations of long-lived satellites and space probes.

The small atomic reactor will heat a closed loop of piping that contains a liquid sodium-potassium alloy and passes through a boiler through which a second loop containing mercury also passes. The liquid metals in the two loops are hermetically sealed from each other, but reactor heat from the molten sodium-potassium passes into the mercury loop. The mercury then vaporizes and drives a miniature turbine-generator set that generates 30,000 watts of electricity.

The SNAP-8 reactor will be the first in the SNAP series powerful enough to generate electricity for propulsion, besides serving as the source of electricity for payload instrumentation. On March 25, NASA announced the selection of Aerojet-General Corp., a subsidiary of General Tire & Rubber Co., for contract negotiations to build the power conversion equipment and to integrate the reactor into an operational system. Atomics International, a division of North American Aviation, Inc., is contractor for the SNAP-8 reactor under contract to the Atomic Energy Commission. SNAP-8 is a joint NASA-AEC project.

CHAPTER 12

MATERIALS AND STRUCTURES

PROBLEMS OF EXTREME TEMPERATURES

Space technology has made it necessary to write new definitions for "high-temperature" and "low-temperature" materials as temperatures generated, utilized, and encountered in space flight range to greater and greater extremes.

Only a few years ago 1,500° F. was considered "high" temperature. Now NASA engineers and contractors who design rockets and spacecraft must deal with temperatures of 5,000° F. and higher, and it is likely that development of propellants with higher energy will extend the upper limits to 8,000° F. and beyond. By way of comparison, the gases of a blast furnace—for years considered the ultimate in heat—are about 3,000° F.

Demands at the other end of the scale are fully as severe. Hydrogen, the most promising of present chemical fuels, boils at -423° F. Liquid oxygen (LOX) and fluorine, two important oxidizers, boil at -297° F. and -350° F. respectively. And the environment in which these chemical rockets will be operating—space itself—approaches absolute zero.

With environmental conditions of these two radical extremes to be met, there is no single material known to science that possesses the combination of complex properties to meet more than a small fraction of the demands.

Ceramics, for example, resist heat fairly well and are good insulators, but most break or crack easily, and are far too brittle for many applications. Various nickel-based alloys and stainless steels will withstand temperatures up to 1,800° F., but if this is exceeded too far, even for a relatively short period, the material begins to soften.

ALLOYS FOR HIGH-TEMPERATURE APPLICATIONS

At NASA's Lewis Research Center, a major effort is devoted to the development of superalloys that can withstand high stresses at high temperatures, even in the presence of corrosive fluids or gases. Such materials are needed for special applications such as the turbopump systems of liquid-propellant rocket motors which employ fluorine, a chemical that will strongly attack most known metals and plastics. Liquid metals are of interest as heat transfer fluids for space powerplants. Since "like dissolves like," their containment by other metals is also a serious research undertaking.

Exploratory work at Lewis is developing a series of new nickel and cobalt-based alloys having excellent strength at temperatures above 1,800° F. Future research will be directed chiefly toward investigating the malleability, or "workability" of these alloys, while maintaining the strength already achieved. These are of considerable potential for auxiliary turbines in liquid rockets.

REFRACTORY METALS

The refractory ("hard to melt") metals—tungsten, tantalum, molybdenum, and columbium—are among the most promising materials for many applications (such as rocket nozzles, for example), at temperatures above 2,000° F. However, they oxidize very rapidly, which restricts their usefulness except in nonoxidizing environments. Fortunately, the near vacuum of space falls in this category.

At Lewis Research Center work has been centered on tungsten, the refractory metal with the highest melting point—about 6,150° F. A most promising material for solid-propellant rocket nozzles, tungsten also offers possibilities as a high-temperature structural and shielding material for space-propulsion systems of the future.

The chief drawback of tungsten is its brittleness; it is difficult to bend or fabricate at ordinary temperatures. Research at Lewis is aimed toward understanding and overcoming the factors responsible for the brittleness. Since it is believed that very small amounts of impurities in the tungsten may make it brittle, one research objective is to produce tungsten of ultrahigh purity, to find if it will be easier to bend and work. To date, very pure tungsten has been prepared by melting in high vacuum. The material has shown good bend ductility at room temperature; research is continuing to establish more definitely the factors involved.

Another study in progress at Lewis indicates that the strength of tungsten is affected by surface flaws—even minute surface scratches. It was found that by electropolishing to remove surface roughness, the bend ductility of tungsten rods at room temperature could be increased sevenfold. These results should be of immediate interest to organizations that fabricate experimental shapes from tungsten sheet.

Research is also being conducted with the goal of producing alloys, based on tungsten but more ductile than the pure material at room temperatures and stronger at high temperatures. Tungsten-tantalum and tungsten-molybdenum alloys have been successfully melted experimentally, and attempts to learn more about the grain structure are underway.

At Langley Research Center the refractory metal molybdenum is being investigated for structural applications. One of the chief shortcomings of this material is that it is difficult to work and weld into structural entities. The strength of spot welds and fusion welds in molybdenum sheet were determined; the compressive strength of "sandwich" structures was measured at temperatures as high as 3,000° F., and studies were made of the mechanical properties of sheet that had been coated with another material to protect it against oxidation. Findings indicate that coated molybdenum alloy sheet can be profitably employed in entry vehicle structures.

REFRACTORY CERAMICS

Several of the refractory ceramics under study at Lewis have even higher melting points than tungsten, and will undoubtedly find use where the very highest operating temperatures are required. Very pure hafnium carbide (melting point, over 7,000° F.) is being prepared, and a density of better than 98 percent of that theoretically obtainable has been achieved—a higher density than any reported before.¹⁸

¹⁸ Commercially available hafnium carbide, for example, has a density of about 80 percent.

Properties of the material are now being evaluated. The work may eventually yield information much more promising for structures that must operate at extremely high temperatures.

The properties of another promising refractory ceramic—tantalum carbide (melting point 7,000° F) are being studied to determine the effect of varying the carbon content. Information gained will aid in tailoring the composition of the carbide to obtain greatly improved physical and mechanical properties.

IMPROVING HEAT-RESISTANT ALLOYS AND REFRACTORY METALS

Aluminum powders can be put through a series of chemical operations ("compacting," or packing very tightly; "sintering," or turning into a solid mass without actually melting; and "extruding," or forcing through dies under pressure) to form materials with unusual strength and stability at high temperatures. The improved qualities result from the fact that the thin film of stable oxide which forms on the surface of aluminum by natural process becomes distributed in the form of fine particles all through the material.

If an analogous structure could be produced in metals other than aluminum, strength and use temperatures could be increased. However, other materials by nature do not oxidize at the surface in the same way or degree that aluminum does; oxides must be added to the products artificially. The potential of the method has stimulated hundreds of experiments in laboratories throughout the world, but improvements achieved have been minor in comparison with the theoretical possibilities.

At Lewis Research Center, the approach has been to study the stabilities of various types of oxides in different metals, and to try different dispersions and degrees of fineness. Results have improved gradually, but are still a long way from achieving the theoretical potential.

Finer and finer dispersals of oxides in metal have been produced in experiments by reducing the sizes of the metallic particles. Methods have been evolved for reducing particle sizes in many kinds of metals, using several types of grinders. Work in this field is continuing, and in the future will be expanded to materials that already show good strength at high temperatures, where it is felt that powder metallurgy methods developed to date can best be capitalized.

NOZZLE MATERIALS FOR SOLID-PROPELLANT ROCKETS

The nozzles of rockets powered by solid fuels must withstand not only high temperatures (5,000° to 6,000° F. and higher) but also the extremely corrosive effects of the rocket exhaust gases. Developing suitable materials for this application is a major problem.

Lewis Research Center has installed and test-fired a small, solid-propellant rocket engine designed to simulate the composition and temperature of exhaust gases of full-scale engines. The device will be used to study the metallurgy of nozzle materials and to learn how and why they fail. This investigation should provide a better scientific basis on which to select and develop promising materials.

The facility proved satisfactory in the initial tests at temperatures of 4,800° F. In future firings, propellants will contain powdered

aluminum, which burns with an extremely intense heat, to give higher exhaust gas temperatures—first, 5,600° F., then, more than 6,000° F.

BEARINGS FOR USE AT CRYOGENIC TEMPERATURES

The use of cryogenic propellants (—200° F. and below) such as liquid hydrogen, liquid oxygen, and fluorine as rocket propellants involves difficulties in lubricating moving parts of a nature never before encountered. Problem areas include bearings, seals, gears, and many other mechanical components of rocket engine pumps and turbines that make sliding or rolling contacts. Conventional lubricants and bearing materials are almost totally unsuitable. For example, ordinary grease will explode in the presence of liquid oxygen.

In present design concepts, to keep turbopump systems as light and simple as possible, the fluid that is pumped does double duty as a bearing lubricant. Lewis Research Center has conducted experiments with bearings operating in liquid fuels and liquid oxidants at cryogenic temperatures. Ball bearings have been operated successfully in liquid hydrogen at shaft speeds of up to 30,000 revolutions per minute. Sliding bearings will also be tested for possible application with oxidants.

OTHER MATERIALS STUDIES

EFFECTS OF NUCLEAR RADIATION ON METALS

In another phase of the effort to produce materials capable of withstanding severe conditions, Lewis is investigating the effects of nuclear radiation on metals.

Work is concentrated largely on the so-called diffusion process, in which individual atoms in metals and alloys move or migrate, producing voids or weakening gaps in the atomic structure. Most present theory is based on studies of diffusion caused by internal strains produced mechanically. In experiments to date, the rates at which voids grow in silver are being measured, and the magnetic properties of nickel-palladium alloys are being compared before and after mechanical stress and/or nuclear radiation. Void growth study is producing results that are in good accord with earlier theory. The nickel-palladium work shows that internal strains affect magnetic properties appreciably. Techniques developed so far will be developed and used in further studies.

STUDIES OF FATIGUE STRENGTH

During the lifetime of an aircraft or missile, many structural components are subjected to gusts of wind, buffets, noise of great intensity, aerodynamic heating and pressure, and other loads and stresses. Cumulative effects may keep building until structures are weakened, and eventually fail. It is difficult to predict this kind of "fatigue" damage by experimental means.

In past investigations, stresses of a particular type have been repeated until the test structure failed. Recently, however, the Langley Research Center has completed a series of tests in which structures were subjected to much more complicated stresses to simulate the typical loads of transport aircraft. These tests indicated that a simple hypothesis, based on cumulative damage, can be employed to

make reasonably accurate forecasts of how long a structure can resist fatigue.

ABLATION MATERIALS

Theoretical and experimental studies of the ablation process (described in NASA's "Second Semiannual Report to Congress") are being carried out at Langley Research Center. In wind tunnels employing electric arcs to heat the airstream, various materials are subjected to conditions of severe heat similar to those encountered when a vehicle enters the atmosphere. The work is yielding information that is useful not only in determining the effectiveness of a wide variety of ablation materials, but also in providing insight into the nature of the ablation process.

Recent analyses show that a water-cooling system in the vehicle structure on the back surface of an ablating heat shield will give good results and—more important—will permit the overall weight of the vehicle to be reduced significantly.

Materials for winged entry vehicles

Another method of reducing aerodynamic heating on the surfaces of a vehicle entering the atmosphere is to use wings to retard the descent and thus to decelerate at high altitudes. The intensity of heating is lessened, but it lasts for a longer time, in comparison with a wingless vehicle. Also, the leading edge—the part of the wing that meets the air first—still undergoes temperatures of 3,000° to 4,000° F.: too high for most materials but not unreasonable for some refractory materials, such as graphite.

Langley is investigating graphite to determine if it can withstand the great heat encountered by leading edges. Graphite is unusual in that over certain ranges of temperature it grows stronger as temperature increases, and shows excellent resistance to heat shock.

Leading edges of various designs constructed from two types of graphite were exposed to a 9,000° F. airstream for periods as long as 5 minutes, to determine how much the material would oxidize and wear away. Because much of the surface heat is radiated to the atmosphere, the maximum temperature the leading edges actually experienced was about 3,500° F., typical of the temperature expected during entry. The tests indicate that graphite can withstand such temperatures structurally, but that its resistance to oxidation must be improved.

CHAPTER 13

MECHANICS OF SPACEFLIGHT

EXTREME CONDITIONS INVOLVED

Flight control of space vehicles and advanced aircraft poses many new problems originating in the extreme conditions of time, space, and speed at which these vehicles operate. In space, the forces affecting a vehicle are extremely small. In the atmosphere, forces affecting flight may be extremely large. Control and stabilization systems, whether for unmanned or manned spacecraft, must cope with both extremes. In space, vehicles undergo zero or near-zero gravity. On entering the atmosphere, they are subjected to forces many times greater than the force of gravity.

High-speed flights in the atmosphere or in near-space and flights into space require novel navigation, guidance, control, and stabilization techniques and detailed understanding of flight trajectories as influenced by the earth's gravitational attraction. In some cases, the attraction of the moon, sun, and planets must also be taken into account.

These and many other factors interact to create problems that must be solved before highly reliable spacecraft, unmanned and manned, and advanced aircraft can become realities. Work typical of NASA research in spaceflight mechanics is highlighted below.

CONTROL AND STABILIZATION

PILOTED SPACE VEHICLES

During more than 50 years of powered flight, highly efficient aerodynamic surfaces have been developed to meet a multiplicity of climb, turn, speed, landing, and takeoff requirements. The pilot has at his command the rudder, trimming tabs, elevators, stabilizers, ailerons, flaps, etc., which he pits against the flowing mass of the atmosphere to trim and maneuver the airplane. In addition, he utilizes atmospheric forces to slow or damp aircraft gyrations.

Wholly different are the forces with which a space pilot will have to cope during orbital flight and entry into the atmosphere. To control and adjust his craft, he must use built-in reaction sources—for example, thrust from small rockets. Nor in space can he rely on natural damping effects, because in the void there is nothing substantial to resist flight motions. For practical purposes, visual perspective is also nonexistent because space has no succession of landmarks at near intervals upon which to take sightings and maintain or correct flight courses. The pilot will therefore have to rely totally on instruments to keep him informed as to the position and orientation of his vehicle.

Simulated spaceflight

Simulation, a useful research technique for many years, is becoming even more important as we progress with the design of spacecraft and

hypervelocity vehicles to be flown by human pilots. Clearly, we cannot simply build a vehicle from an untried design and ask a man to attempt flight in it. Hence, many ingenious research tools have been developed in which most of the characteristics of actual flight can be reproduced in the safety of the laboratory.

The Langley, Ames, and Flight Research Centers have in use and are building several advanced simulators to test pilot capabilities in various types of spacecraft.

Ames five-degrees-of-freedom simulator

Nearing completion is a simulation facility more highly developed than any of its predecessors in creating for a pilot the illusion of genuine flight. The simulator consists of an enclosed cockpit or cab mounted on triple gimbals. It will be capable of impressing three angular motions on the pilot-subject. The cab is mounted on an arm 30 feet in radius in such a way that it can move vertically while the arm is rotating. In this way, five mechanical degrees of freedom are provided - three angular and two linear.

The pilot will be enclosed in the cockpit and provided with controls and flight instruments appropriate to the vehicle being simulated. The controls are connected to an analog computer in which the responses of the vehicle to the pilot's actions are calculated. Signals from the computer are then used to drive the cockpit electrically, thus translating the analog values into motions. Cockpit instruments furnish the pilot the same information he would receive in actual flight. Thus he can be given the motion stimuli and the visual instrument reading pertinent to the vehicle characteristics and the flight conditions under study.

Langley fixed base simulators

At Langley, one approach to control and stabilization problems employs a simulator consisting of a fixed cockpit equipped with controls and instrument displays in conjunction with an analog computer. Encouraging progress has made in several problem areas, including that of controlling a spacecraft during the strong disturbances caused when retarding or retrorockets are fired to break out of orbit and start descent into the atmosphere. After several control arrangements and instrument displays were studied, a system was devised that permits the pilot to control the simulated vehicle satisfactorily.

Similar means are being employed to develop techniques for the rendezvous of two vehicles in space.

Attitude control by a flywheel magnet system

The attitude of a space vehicle is determined by the inclination of its axis to some frame of reference. Usually the frame of reference is coordinates of the earth, although coordinates of the moon, sun, or a planet could be used. For most missions spacecraft attitude must be known and controlled precisely. Observations for navigation and guidance depend upon proper setting and monitoring of attitude. Flight path control depends on correct attitude control so that retrorockets can be fired in precisely the right direction and right duration for adjustments.

Solid rockets will not be suitable for controlling satellites that demand precise and continuous attitude trim in earth orbits, or for spacecraft on missions to far-off destinations. In both cases, ad-

justments may have to be made again and again, and thus schemes that can provide long-term control are required.

Langley is investigating a promising attitude-control system. It employs the reaction from a small accelerating flywheel to swivel a vehicle to the desired attitude, and uses the flywheel in concert with permanent bar magnets that allow the flywheel to despin and so maintain attitude trim over extensive periods. A bench-test model has performed well in tests. An analytical study of the system indicates that it can be developed to meet many of the requirements for satellite-borne astronomical telescopes and for intermediate guidance of spacecraft on long voyages.

Based on results from this model, Langley is completing a three-axis elaboration of flywheel-magnet control. The equipment will be employed to investigate many operational characteristics of the system.

Vehicle control within the atmosphere

Ultraswift high-flying aircraft, vertical takeoff and landing aircraft, and manned spacecraft entering the atmosphere share several types of control problems which NASA is continuing to investigate.

Because modern craft operate at extreme velocities and altitudes and are maneuvered under a number of new circumstances, mechanically powered controls and special flight data instruments are required. Interplay of these and other factors strange to natural human conditioning makes it increasingly difficult for the pilot to interpret cues from the controls and flight data instruments accurately and to act upon them swiftly and correctly.

NASA research centers have untaken a number of studies concerned with the "feel" of manual controls, the effects of vehicle dynamics, and the significance of cockpit flight-control instrumentation on man's ability to control various classes of aircraft and space vehicles.

One phase is nearly complete. This is a flight-test program to investigate the effects of using varying degrees of induced feedback to supply control "feel" to pilots, and is analyzing the results. The analysis should provide guidance for designing direct-control systems as well as power-operated control systems.

Another NASA investigation related to pilot control has found that aircraft—and in all likelihood, manned spacecraft to come—can be more precisely controlled, particularly during high acceleration by the use of a "side-arm controller" in place of conventional sticks or wheels and rudder pedals. The device consists of an armrest beside the pilot, with a small control stick or knob actuated by finger or wrist motions. At present, NASA is seeking configurations with which control movements can be better confined to the desired direction, in which force-feel characteristics are suitable, and in which hand movements can be as natural as possible. The investigation is employing a simulator, incorporating a pilot's instrument displays of control reactions, and the various controller types under study.

Three-axis simulator investigations of signals

Factors that influence a pilot's ability to control advanced types of vehicles by reference to instruments have been studied at Langley. Conventionally, speed rates and vehicle attitude signals are fed to separate display instruments in the cockpit. This keeps the pilot constantly comparing two instrument readings in order to maintain

speed and attitude in correct relationship. From the Langley work, a successful method has been devised for displaying both types of information on a single instrument simultaneously.

Adaptive control system

To cope with the wide range of conditions encountered by modern aircraft and space vehicles, NASA is making an analytical study of an adaptive control system. Automatically, this system senses changes in flying circumstances and makes adjustments to the control system so that the vehicle will respond efficiently to control input over its total range of operation. Adaptive controls promise to be reasonably uncomplicated and to provide versatility to manned as well as unmanned vehicles.

GUIDANCE AND NAVIGATION

ENTRY CORRIDOR POSSIBILITIES

The atmosphere of the earth is an effective, natural braking medium which, if properly employed, may eliminate need for retrorocket braking systems on entering spacecraft. This, in turn, would reduce the takeoff weight of a space vehicle.

At Ames Research Center, a continuing study of entry orbits from lunar flight has disclosed a particular segment of the earth's atmosphere that may permit entry without use of retrorockets. This region is called an entry corridor.

Should a returning spacecraft enter the atmosphere too high to come within the desired corridor, the vehicle may depart from the atmosphere and travel over a distant orbit before returning again to the vicinity of the earth. An entry too low to find the corridor could well subject the spacecraft and its payload to deceleration forces intolerable to human beings or damaging to the structure. Ideally, a returning spacecraft would be guided into the precise corridor that would permit the drag or retarding effect of the atmosphere to slow the vehicle just enough that it would remain inside the atmosphere once its descent is begun.

Ames analytical study

Selection of a precise returning trajectory is therefore critical if atmospheric braking is to be used for decelerating a space vehicle. An analytical method for calculating such trajectories has been derived by Ames scientists. Tables of mathematical functions are being compiled for publication. The tables will permit trajectory studies to be made without drawn-out calculations. The Ames technique for trajectory analysis applies to vehicles of arbitrary weight, shape, and size entering the atmosphere of the earth or of any other planet that is blanketed with gases.

Aerodynamic lift aids entry

Studies applying the analytical method have disclosed that the safe entry corridor can be expanded markedly if the entering vehicle is able to generate moderate amounts of aerodynamic lift. In a typical case, corridor depth can be increased from seven miles to 51 miles with a vehicle capable of a 1-to-1 lift-to-drag ratio. By comparison, modern transport airplanes customarily fly at lift-to-drag ratios of 15 or more.

TRAJECTORIES

Before a spacecraft can be designed for a mission and an operational schedule planned, the trajectory and associated energy requirements must be worked out with precision. At Lewis Research Center, NASA is utilizing large electronic computing machines for plotting space voyages in trajectories that compensate for gravitational attraction exerted on the vehicle by the sun, together with that of any five planets in the solar systems. (Restriction to the sun and five planets arises from information-storage limitations of the computer.)

It is convenient but inaccurate to speak of a space vehicle as "escaping the earth's gravity." In reality, every single body in space is always influenced to some extent by all other bodies in the universe. The earth's gravitational pull, for instance, extends to infinity, becoming weaker with distance but never altogether ceasing. If these forces could be visualized, space would resemble a giant cat's cradle of thick lines (for powerful attractions from large bodies in the solar system), and would be cross-hatched by countless spidery lines (representing gravitational forces attenuated over tens and millions of light-years from other solar systems and galaxies). This gives a faint, oversimplified idea of the maze of forces—whose centers are constantly in motion and therefore in ever-changing relationship—through which the trajectories of spacecraft must be calculated to thread with great accuracy.

Computer use

In NASA's trajectory program, such problems are being programmed for an IBM 704 digital computer. Already the computer has been employed to determine how the oblateness (pear-shape) of the earth and solar and lunar perturbations will affect ballistic flights to the moon. Currently, the computer program—largely the responsibility of Lewis Research Center—is determining the effects of multi-body perturbations on steering for low-thrust (that is, ion and plasma jet) space vehicles on interplanetary missions.

Precise and simplified calculations

A major problem in calculating precise trajectories is the length of time it takes a computer to handle the multiplicity of factors involved. The time element, plus expense, makes it impractical to utilize the precision program to survey large groups of possible trajectories for different missions. Such surveys can be conducted economically and swiftly by using approximate solutions which indicate areas of greatest promise for spaceflight. Trajectories in these areas can then be checked with the precision program.

Mars and Venus trajectories

Digital computer programs that will approximate trajectories for lunar and interplanetary missions are in progress at Lewis. Included are calculations of trips to Mars and Venus. The studies include both minimum-energy trips, using long coasting trajectories, and maximum-energy missions in which flight times may be halved by providing more fuel for longer engine use.

INVESTIGATION OF LUNAR "SOFT" LANDING TECHNIQUES

The NASA Space Flight Program includes plans to use an Atlas-Centaur vehicle for making a "soft" landing of instrumented payloads of modest weight and instrumentation on the moon in the 1962-1963 period. Soon thereafter, larger and more complex payloads are to be similarly landed by the Saturn launch vehicle. The principal difficulty in making a soft landing on the moon is to reduce the speed of the vehicle from 6,140 miles per hour (minimum impact speed if no braking force is applied) to essentially zero when it reaches the surface of the moon. If zero velocity is reached too soon—say at an altitude of 1,000 feet—the vehicle will accelerate and crash. Thus the velocity must be neutralized by backward firing or retrorockets (since there is no atmosphere to give "drag" to a parachute) at a precisely calculated altitude, amount of thrust, and time. If the retrorocket does not produce a thrust that exactly compensates for the motion of the vehicle, velocity will not be reduced and the payload will crash.

Lewis Research Center began investigating these and related problems in September 1959. First came an engineering analysis and design of an unmanned lunar soft-landing research vehicle (compatible with the boost capabilities of Atlas-Centaur), capable of studying details of systems for stabilizing attitude, and for measuring altitude, attitude, velocity, and direction of motion with respect to the surface of the moon.

The next phase, now in progress, consists of a series of research programs to study the major problems facing the designer of a lunar soft-landing vehicle, and designing and testing the lunar research vehicle. Work will culminate in a series of tests in which the vehicle, weighing about a ton, will be dropped from an airplane and brought down to soft landings on the earth entirely by the use of retrorockets. First, however, numerous such landings will be simulated, ending about a thousand feet above the earth's surface, where parachutes will be deployed to lower the vehicle safely to earth so it can be recovered, modified, and reused.

One of the most important problem areas to be studied with the test vehicle will lie in the control of its attitude while the retrorocket (6,000-pound thrust) is burning. Should the fuel sloshing in the tanks move the center of gravity only an inch, the vehicle will rotate 60° in about a second, unless the attitude control system restrains it.

Flexibility will be designed into the test vehicle to allow interchanging various control systems. For example, four small jets around the vehicle may be used to hold attitude, or the main engine may be gimballed to permit swiveling. The small jets may discharge cold gas from a pressure bottle, or hot gas from rockets.

In other areas, such as control of thrust and duration of thrust of the retrorockets, the tests with this vehicle will be used to study the alternatives, and if possible, improve the precision of the one selected. Work on these and other problems related to lunar soft landings are under way at the other research centers.

Midcourse trajectory corrections

As part of the long-range objective to land large payloads on the moon and planets, NASA has undertaken a number of studies of guidance during midcourse flight. At Lewis a study of requirements for correcting the course of spacecraft en route is in progress. This study will have two phases: (1) to study the amount of correction necessary for various initial errors and where this correction can best be applied; (2) to supply some of the information necessary for developing the rocket or other system needed to provide the correction. For the latter purpose, preliminary experimental work in the Lewis altitude wind tunnel is underway on small rockets employing storable-liquid, hypergolic propellant (bursting into spontaneous combustion when its elements are combined).

CHAPTER 14

AERODYNAMICS, FLUID MECHANICS, AND ENVIRONMENTAL PHYSICS

AIRCRAFT AERODYNAMICS

The study of conventional aircraft that fly within the atmosphere continues to be an important part of the work carried on at NASA's Langley and Ames Research Centers.

It might be thought that the space effort has tended to push work on conventional aircraft into the background, but NASA is continuing the research function that NACA, its predecessor, performed for more than 40 years. Furthermore, many of the studies of problems relating to aircraft can be carried over and applied to spacecraft—particularly those relating to supersonic and hypersonic speeds. Spacecraft plunging into the atmosphere experience the same kind of aerodynamic heating—different only in degree—as do high-speed conventional aircraft.

The science of fluid mechanics (which is concerned with the motion of both gases and liquids) is directly applicable to aircraft and spacecraft problems alike, and generally precedes advanced applied research on the aerodynamics of aircraft, missiles, and space vehicles. The centers are therefore continuously involved in an across-the-board effort in fluid-mechanics fields dealing with the properties of gases at high temperatures, boundary-layer and heat-transfer characteristics, low-density gasdynamics, and magnetogasdynamic and plasma physics (the latter fields pertaining to the study of electrically conducting gases and their interaction with magnetic fields).

NASA is engaged in research across the entire speed range of aircraft, from VTOL (vertical takeoff and landing) aircraft that can take off and land at zero forward speed to the rocket-boosted Dyna-Soar glider with which the U.S. Air Force plans to explore the range between about 4,000 m.p.h. and satellite speeds of about 18,000 m.p.h.

Some of the representative programs underway in NASA research centers are summarized in the sections that follow.

FLYING QUALITIES OF HELICOPTERS AND VTOL AIRCRAFT

Strong emphasis is being given at the Ames and Langley Research Centers to developing helicopters, VTOL (Vertical Takeoff and Landing), and STOL (short takeoff and landing) aircraft having safe handling qualities. Flight tests are underway at Ames on two VTOL airplanes utilizing the tilt-rotor and deflected-jet propulsion-lift concepts; at Langley tests are in progress on a tilt-wing aircraft, and preparations are being made for flight tests of a tilting ducted-fan aircraft.

The Langley program with the variable-stability helicopter (in which the control characteristics can be varied to simulate those of other aircraft) is providing information useful in the design and

development of both helicopters and other VTOL/STOL aircraft. Additional information of this type will be obtained from the variable-stability VTOL vehicle now being prepared at Ames. Wind-tunnel and ground-based simulation studies have also been made to provide information on some of these aircraft. Results make it possible to predict and correct adverse characteristics prior to flight, and to evaluate configurations that have not yet reached flying status. Information obtained from such studies should be of great value in determining the relative effectiveness of the various VTOL/STOL concepts and in formulating general flying-quality requirements for this class of aircraft.

SUPERSONIC-TRANSPORT AIRCRAFT

Wind-tunnel investigation of representative supersonic-transport configurations—including those with variable-sweep wings—has continued at Langley; special attention has been given to obtaining general information on ways of improving flap effectiveness in landing and takeoff. In preparing for a full-scale wind-tunnel investigation of a supersonic transport configuration to be conducted at Ames, staff members visited various aircraft companies to insure that the model would incorporate representative components.

MULTIMISSION AIRCRAFT

The Langley Research Center has devoted extensive effort during the last few months to the development of a multimission military aircraft. A variety of configurations have been investigated in subsonic, transonic, and supersonic wind tunnels. These studies were based on the assumption that, from the standpoint of both economic and military effectiveness, it would be highly desirable to combine long subsonic range for ferry and "loiter" purposes, efficient supersonic performance for high-altitude attack missions, and good landing and takeoff characteristics for carrier aircraft or shortfield operation. Inasmuch as it seems improbable that a fixed-wing aircraft can accomplish all these missions satisfactorily, research is being directed toward variable-sweep configurations.

RESEARCH ON JET EXHAUST EFFECTS

The shape of the jet exhaust emitted from high-speed aircraft and space vehicles is important in analyzing the temperatures and pressures on the base and afterbody. Using a mathematical approach, Lewis scientists have worked out simple expressions for estimating the shape or contour of a jet exhausting into a supersonic airstream, and for comparison, into quiet air.

The effects of jet "billowing" of the exhaust gases at high altitude on the stability of two missile-shaped bodies were investigated experimentally at Lewis. At a Mach number of 3.85 results indicated that the stability of the bodies, which had no wings or tail surfaces, was not adversely affected by the interference effects. On an airplane, such as the X-15 for example, the interference was shown to be detrimental.

A mathematical formula was also developed to determine how much pressure the jet and the supersonic stream around it will apply on tail and control surfaces of the vehicle. The formula was tested experi-

mentally by measuring the pressure influence of the jet on a flat metal plate.

FLUID MECHANICS

PHYSICS AND CHEMISTRY OF GASES AT HIGH TEMPERATURES

Heat transfer experiments are being carried out at Lewis in a flow tube and in a shock tube. From these experiments comes information about processes that occur on a molecular scale, such as the exchange of energy between molecules, and the effects of chemical reaction on heat transfer.

Recently completed were studies of the thermal conductivity of a reacting gas and measurements of heat transfer where a large temperature difference exists between a hot gas and an object being heated—such as a rocket nozzle. The knowledge gained can be applied to problems of cooling or estimating the heating of rocket engines, hypersonic vehicles, and spacecraft entering the atmosphere.

High-temperature chemical reactions are being studied directly in a special kind of shock tube. The last six months have been devoted to improving its performance, and data are now being collected. This device is able to heat a mixture of gases to extreme temperatures in a very short time, hold it at high temperature for a known time while reaction occurs, and then cool the mixture almost as quickly, thus stopping the reaction abruptly. Reactions among carbon dioxide, carbon monoxide, water vapor, and oxygen are being studied. These processes are important in the flow of gas from a chemical rocket through the exhaust nozzle.

Another facet of high-temperature reactions is being studied by means of "detonation waves" which consist of a chemical reaction and a shock wave coupled closely together and traveling at supersonic speed. The conditions under which the waves can exist are being determined, and results are being analyzed theoretically.

INTERACTIONS OF IONIZED GASES

A fluid that is raised to very high temperatures, or is in the presence of strong electric and magnetic fields, becomes ionized, and as a result conducts electricity. Ionized fluids can be greatly influenced by external electric and magnetic fields and are important in connection with space propulsion and thermonuclear devices. Several research problems in which the interactions of ionized gases with external fields are being investigated are described below.

Electrically conducting fluid flows around a body

If an electrically conducting fluid flows about a body, a magnetic field set up by apparatus within the body can modify the flow. This phenomenon is of particular interest because a spacecraft entering the atmosphere encounters such conditions, the air possessing the attributes of weakly conducting fluid. A practical application of this principle could result in changing the pressure distribution on the surface of an entering vehicle, altering both the total drag and the characteristics of the boundary layer.

Lewis Research Center is carrying out a project to determine the changes of pressure distribution on several body shapes, cylinders and spheres, in uniform streams, when magnetic fields are emanated

from the body. Tests so far have consisted of simple circular or "dipole" magnetic fields, and their effects on drag control and surface cooling (boundary layer control). Work on this project is continuing.

Other related studies include mathematical analyses of the way magnetic-field changes in the boundary layer will affect the total drag of the body and the amount of heat transferred to the body's surface, (Previous studies have been concerned only with the hottest portion, or "stagnation point.") These analyses will trace how the boundary layer develops around the body. A large digital computer is being employed for the work.

SPACE ENVIRONMENT PHYSICS

MICROMETEOROID IMPACTS STUDIED

Many U.S. satellites and space probes have carried devices to measure micrometeoroid (or cosmic dust) impacts.

Impacts of small microparticles on thin, multiple-skin structures are being investigated at Ames. The targets consist of sheets of metal, spaced apart, and in some tests, interleaved with insulating material.

Under study are resistance to penetration of various types of material, skin thicknesses and spacings, and insulating material. Projectiles are chosen to simulate micrometeoroids; glass spheres, $\frac{1}{8}$ inch in diameter, are used in many of the tests.

Some results from firing these spheres into aluminum alloy sheet are now available. The combined thickness of all sheets was held to $\frac{1}{16}$ inch. Spacing and number of sheets were varied. In one test, the space between a two-sheet target was filled with fiberglass insulation. Velocities of projectiles were increased until they perforated the target. The velocity at this point is called the ballistic limit. During tests, the projectile itself always shattered on impact with the first sheet of the target.

It was found that the ballistic limit of two sheets, spaced half an inch apart, was almost double that of a single sheet of double thickness—4,100 feet per second for the two sheets as against 2,200 feet per second for the single sheet. Increasing the spacing of two sheets from $\frac{1}{2}$ inch to 1 inch increased the ballistic limit by 35 percent, to 5,500 feet per second. However, for a given spacing, increasing the number of sheets from two to four gave only a small increase in the ballistic limit (from 4,100 to 4,300 feet per second at $\frac{1}{2}$ -inch spacing, and from 5,500 to 6,000 feet per second at 1-inch spacing).

A substantial additional increase in ballistic limit¹⁹ (10,000 feet per second) was produced by filling the space between the sheets of a two-sheet, one-inch space target with two layers of fiberglass insulation. The fiberglass increased the total weight by 20 percent, so that it is not strictly comparable to the other targets employed. However, it is reasonable to anticipate that the covering of a spacecraft built as a doublehull, with fiberglass insulation filling the space between the hulls, will weigh only about a third as much as a single skin giving equal protection from micrometeoroid impact.

¹⁹ By way of comparison, this is approximately the same ballistic limit as that of a sheet of aluminum alloy three times thicker ($\frac{3}{16}$ inch) than those used in the tests.

PHOTOCHEMISTRY OF UPPER ATMOSPHERE GASES

Although the density of the earth's upper atmosphere is being determined from sounding rocket and satellite data, the nature of its composition is yielding to measurement much more slowly. The difficulty stems chiefly from lack of knowledge of the rate at which oxygen atoms recombine to form molecules after being split apart by ultraviolet rays from the sun.

Ames Research Center has assembled and operated apparatus to measure this rate by means of oxygen atoms and excited molecules produced by electrical discharges in a low-pressure tank.²⁰

ION BEAM EXPERIMENTS

The necessity for understanding the environment in which spacecraft will operate have called forth new, unconventional research tools to aid the laboratory scientist. One such device at Ames is the ion accelerator. An atom that loses one or more of its electrons is known as an ion. It possesses a positive electrical charge. The Ames ion accelerator, which produces a stream of ions at very low density and high velocity, has yielded useful results in studying the erosion of metal surfaces under bombardment by a stream of ionized (nitrogen) gas.

Erosion rates for common metals—for example, copper—have been determined under bombardment by ion beams head on, at a 45° angle, and at energies ranging from 200 to 8,000 electron volts. The range will be extended downward to about 10 electron volts, and oxygen, hydrogen, and helium will be used in addition to nitrogen. Also planned are investigations of emissivity changes, surface reaction rates, crystal structure effects, and angular distributions of reflected and emitted particles.

²⁰ A device that simulates the low densities of the upper atmosphere.

CHAPTER 15

FLIGHT SAFETY

OPERATIONS AND ENVIRONMENT

The number and size of airplanes, and the speeds at which they fly, are steadily increasing. Problems of maintaining flight safety under crowded and complex traffic conditions are increasing even faster. Research on safety problems, therefore, constitutes a deservedly important part of NASA's overall program, and this research is necessarily of a widely varied nature. Typical programs are highlighted below.

STUDIES OF ALTIMETRY PROBLEMS IN AIRPLANE OPERATIONS

The degree of accuracy to which a pilot knows his altitude, and his performance in staying within his assigned altitude levels, largely determines the nominal vertical separation that must be maintained between his flight path and those of other airplanes on the same airway. To a considerable degree, this assigned separation determines how much traffic the airway can handle.

As air traffic has grown heavier, and faster, the need has become pressing to reexamine the accuracy of altitude measurements and maintenance of prescribed flight paths to avoid collisions and at the same time assure that airways capacity is not unduly limited. Langley Research Center is investigating these problems.

Nearing completion is a study on the accuracy that altimeters maintain over long periods of service. Regulations call for an altimeter to be calibrated for accuracy only once. Altimeters of four types now in use are being tested to check long-term stability of calibration under conditions that simulate those of usual flight operations.

Conventional pressure-sensing altimeters become less accurate at high altitudes. Accordingly, pilots of jet aircraft must maintain greater vertical separation at these altitudes. NASA is surveying all known altimetry systems, and those having promise for improvement will be studied further.

Altimeter accuracy is also a critical factor in instrument landings when visibility is poor. The pilot generally relies on the altimeter in conjunction with guidance from a ground-based radio beam known as the instrument landing system (ILS). Obviously, the accuracy of both the altimeter readings and the ILS glide slope determine the minimum conditions of visibility and ceiling under which instrument landings can be made safely.

Langley is testing the accuracy of altimeters and the ILS to establish minimum safe visibility standards. True height is being measured for different types of airplanes in many landings for which pilot's readings of altimeters and ILS indications are recorded for comparison.

Another Langley investigation is determining how closely pilots or autopilots maintain assigned altitude levels—the so-called flight

technical errors. Now in its first stages, the study consists of a statistical analysis of altitude records from NASA flight recorders installed in commercial transport and military airplanes. Effects of such factors as airplane type, cruise altitude (as high as 40,000 feet), and atmospheric turbulence will be assessed.

DOWNWASH EFFECTS ON VTOL AIRCRAFT

An inherent problem of VTOL (vertical takeoff and landing) aircraft is the strong downwash they produce. It is powerful enough to hurl loose material from the ground into the air. A craft with large rotors will hurl sand and dust. Propeller-driven machines will pick up gravel. Jet engines will throw even heavier objects. Effects may range from mildly impaired visibility to serious damage to the aircraft or its engines. The problem could severely restrict VTOL operations, particularly with military craft whose usefulness will depend to a large extent on being able to take off from or land on unprepared terrain.

Langley is investigating characteristics of VTOL downwash flows. By taking pressure measurements and using smoke or other flow visualization techniques, characteristic down flows are being determined; results should permit predicting the effects of the downwash and aid in developing operating techniques to reduce or counteract them.

NOISE SOURCES ON SUPERSONIC TRANSPORTS

Although 2,000-mile-per-hour supersonic transports, capable of whisking passengers from New York to London in 2 hours, are still in the concept stage, research problems connected with such planes are under intensive study. The serious problem of noise—already familiar from operation of modern jet aircraft—will become much more severe with supersonic craft. The shock wave extending downward from planes flying beyond the speed of sound causes noise like artillery fire, in some cases cracking window panes and otherwise damaging property.

The main sources of noise from the supersonic transport will be threefold: the engines, the aerodynamic boundary layer (the extremely thin, sticky layer of air next to the skin of the aircraft, which behaves like a viscous, friction-creating fluid at the speeds and temperatures involved), and shock waves, which produce the now well-known sonic boom.

Engine noise—of particular concern because of its adverse effects on the airplane structure, ground crews, and surrounding communities—will pose problems similar to those encountered in present jet transport operation. These problems must be considered in early design stages, since they will have important bearing on the choice of structure, powerplant, aerodynamic configuration or shape, and operating practices.

Several thousand pounds of soundproofing material are needed to keep noise levels down in the passenger compartments of present commercial jets. Supersonic transport will undoubtedly require considerably more insulation, chiefly because of the great rise in boundary-layer noise as speed increases.

One type of jet engine, called the turbofan, shows considerable promise by a combination of greater jet efficiency, lower pitched, less

harmful noise, and increased power that permits steeper and faster climbs to move up and away from residential areas.

Research to date shows that sonic-boom intensities cannot be significantly reduced by changing the external shape of an aircraft for a given weight. The only practical solution to the problem seems to lie in controlling speed and altitude in relation to angle of climb. One method—described in NASA's second semiannual report—involves climbing at subsonic speeds to about 35,000 feet before accelerating to supersonic cruise speed; this eliminates the danger of shock wave damage on the ground and keeps annoyance relatively low. Using a variable sweep wing would greatly increase flight efficiency during the climb.

Another method considered promising can be used if the plane has a high enough thrust-to-weight ratio to enable it to accelerate while it is climbing at supersonic speeds. Employing a very steep climb angle can reduce the shock wave's force on the ground. The procedure, however, can be affected greatly by wind changes.

From recent research two other procedures have emerged that may help cut down noise on the ground. Supersonic craft should decelerate from cruising speeds to subsonic speeds while still at a very high altitude (perhaps 60,000 to 70,000 feet), and they should not turn or otherwise maneuver at supersonic speeds, because this concentrates strong pressure waves from the aircraft on small ground areas.

"WAKE" EFFECTS OF LARGE TRANSPORT AIRCRAFT

The strong, eddying air currents, or "wake" of large airplanes such as transports can severely buffet and stress smaller, lighter aircraft crossing the flight path. A theoretical study has been made at Langley of the stresses and loads produced in a light airplane by the whirling washes generated by a large, fast transport. Stresses were calculated to be so severe that the efforts of a lighter plane pilot to master the violent motions of his aircraft could increase the strains until structural failures would result. It seems clear that the only solution is to make sure that light planes keep well clear of the wakes of larger aircraft.

FUEL SLOSHING DAMPERS

Liquid fuels "sloshing" in vehicle tanks can have bad effects upon flight characteristics. Ames Research Center has investigated ways of "damping" or controlling liquid motions. Effectiveness of various types of baffles has been measured for different depths of liquid, and for different speeds and amounts of oscillation.

POWER-OFF LANDINGS FOR LOW LIFT-TO-DRAG RATIO VEHICLES

Many hypersonic aircraft and manned entry vehicles will be of types having wings that produce relatively low lift in comparison to the drag they encounter. Hence, it is difficult for pilots to judge the flight path to position such craft precisely at the runway approach. It is also difficult to judge the correct speed and altitude for leveling off from the steep glide angles typical of aircraft having low lift-drag ratios.

An unpowered landing technique for such vehicles has been developed and flight-tested at Ames. The new technique provides an

explicitly defined flight path for the pilot. The first part of the pattern is a constant descent at high speed along a straight line aimed at a ground reference point short of the beginning of the runway. At a specified altitude, and at a speed corresponding to the programmed angle of descent, the plane is pulled out at a constant rate into a shallow flight path along which the vehicle then decelerates to touchdown.

Flight trials of the technique were made with a tilt-wing test airplane. Using two different configurations, both with low lift-drag ratios (4.0 and 2.8, respectively), the approach patterns as computed from available lift and drag data for the test airplane proved completely satisfactory. Forty-five landings were made by six pilots while motors were idling. Touchdown points of plus or minus 600 feet and airspeed accuracies of plus or minus 10 miles per hour in relation to the predicted conditions were obtained. Pilot opinions of the technique were uniformly favorable.

These significant characteristics of the landing technique were demonstrated by or deduced from the flight tests:

- (1) Individual tasks are compatible with the average pilot's flying experience.

- (2) The technique requires little or no practice.

- (3) The technique reduces the number of variables requiring pilot judgment, and thus landing depends more on aerodynamic limitations of the vehicle and less on pilot skill.

- (4) A missed approach is evident as soon as the plane levels off, at a speed well above that for touchdown, and the pilot has time to eject himself if necessary.

- (5) The pattern, since it is composed of straightline elements, is especially compatible with practical schemes for electronic guidance or automatic control.

- (6) At the high initial approach speeds characteristic of the technique, speed brakes (high-drag structural sections extended into the airstream) are an effective speed control, reducing the need for a precise initial glide angle.

- (7) The initial glide path may be entered at any altitude above that required to stabilize speed, thereby simplifying the problem of navigating to the point at which the descent pattern is entered.

MEASURING PHYSIOLOGICAL CONDITIONS OF PILOTS

Scientists of Ames Research Center, in collaboration with a U.S. Navy flight surgeon, have developed a small, simple, instrument package to record certain vital physiological functions of a pilot in a simulator cockpit or flying an aircraft. In previous research on ability of a pilot to control an aircraft, physiological condition was of secondary concern. In supersonic flight or spaceflight, however, environmental stresses—such as high g forces, weightlessness, and high temperatures—cannot be ignored. It is now necessary to monitor (for safety) and study the physiological reactions of the pilot as well as his performance of a control task.

The Ames physiological instrument package contains three types of measuring devices. The first two monitor blood pressure and heart reaction. The third indicates a breathing rate and the amount

of oxygen consumed, giving a measure of the energy expended by the pilot.

The instrument package, designed to cause as little discomfort as possible, has been demonstrated in flight. It will next be applied to—

(1) A flight-test study of the effects of zero gravity, or weightlessness, on a pilot's ability to solve a control problem, and

(2) Safety monitoring of subjects in the Ames "five-degrees-of-freedom" flight simulator.

MEASUREMENTS OF WINDS AND WIND SHEARS

The winds and wind shears (high altitude air currents moving in the same or different directions at varying speeds) encountered by rocket vehicles can be hazardous to large, flexible, booster combinations. Such currents can set up structural vibrations that can wreck the vehicle or alter its flight path. These conditions become critical at the upper limits of the troposphere, where the combination of the high dynamic pressures of the rocket as it builds up speed and the intense wind shears of the jet stream²¹ lead to severe loads and stresses. (Aircraft are also subject to these effects.)

Information on the detailed wind structure along actual rocket flight paths to altitudes of about 100,000 feet is being obtained by Langley Research Center, through analyzing photographic records of rocket exhaust or smoke trails. Studies of trails from rockets launched at Wallops Station have indicated that wind structure along the flight path is a random disturbance, with shear layers 300 or 400 feet thick moving in various directions through the larger prevailing wind fields, which have been measured from balloon soundings. Wind, temperature, and air density measurements at altitudes of 100,000 to 250,000 feet are also being obtained by using radar trackings of "chaff" (confetti-like reflecting material) or parachute payloads from special rocket firings at Wallops. This work is in cooperation with other rocket-launching ranges in the United States and Canada.

OTHER STUDIES

NASA is continuing to study spacecraft landing problems, inflated-sphere soft-landing techniques, and pilot performance—all reported in considerable detail in NASA's "Second Semiannual Report to Congress."

²¹ A torrent of air that flows from west to east at altitudes of between 20,000 and 50,000 feet.

CHAPTER 16

THE NASA ORGANIZATION

ORGANIZATIONAL DEVELOPMENT

During the period, NASA entered upon several important expanded or new assignments. These included responsibility for developing all high-thrust launch vehicles for the Nation's space program; a key role in the projected United Nation's conference on peaceful uses of space; and establishment of a life-sciences program.

SPACEFLIGHT FUNCTIONS REASSIGNED

Launch vehicle program broadened

On October 21, 1959, the President announced his intention to transfer the Development Operations Division, Army Ballistic Missile Agency (ABMA), Huntsville, Ala., to NASA, unless Congress should disapprove within 60 days as provided in section 302(c) of the National Aeronautics and Space Act of 1958. The President's message was delivered to Congress on January 14, 1960, and took effect on March 14, with NASA gradually assuming responsibility. The actual official transfer of personnel and property will take place on July 1.

NASA was also assigned responsibility for developing all high-thrust launch vehicles for both military and scientific space programs. Increased NASA emphasis on launch vehicle development was reflected on January 1, 1960, when a new Headquarters office was established to direct this program, and spaceflight responsibilities were realigned as follows:

*Office of Launch Vehicle Programs*²²

The new Office is responsible for (1) developing propulsion systems; (2) designing and procuring launch vehicles and associated controls; and (3) NASA launching operations at the Atlantic Missile Range, Cape Canaveral, Fla., at the Pacific Missile Range, Point Arguello, Calif., and other sites. It directs and coordinates operations of the George C. Marshall Space Flight Center and the NASA-Atlantic Missile Range Operations Office. The Office of Launch Vehicle Programs is organized with assistant directors for propulsion, vehicles, and launch operations.

Office of Space Flight Programs

Formerly the Office of Space Flight Development, this Office is responsible for (1) planning satellite and space probe missions; (2) payload design and development; (3) in-flight operation of probes and satellites; (4) tracking, and securing information from satellites and probes; and (5) launching sounding rockets and acquiring and interpreting data from them. The Office directs and coordinates the

²² Directors of NASA Offices are listed in the organization chart, facing p. 121.

activities of the Goddard Space Flight Center, Greenbelt, Md.; the Jet Propulsion Laboratory, Pasadena, Calif.; and Wallops Station, Va. It directs Project Mercury, and is in charge of establishing and maintaining the worldwide Minitrack, Mercury, and Deep Space tracking and data acquisition networks. The Office was reorganized, with assistant directors appointed for: (1) applications and manned flight programs; (2) satellite and sounding rocket programs; (3) lunar and planetary programs; (4) space flight operations; and (5) program planning and coordination.

OFFICE OF AERONAUTICAL AND SPACE RESEARCH REORGANIZED

The Office of Aeronautical and Space Research, renamed the Office of Advanced Research Programs on January 1, reorganized internally in order to conduct a more intensive inhouse effort in research and development of materials required for aerospace programs. A Materials Division to specialize in this work was organized under the Assistant Director for Structures and Operating Problems. The Office of Advance Research Programs directs and coordinates operations of Langley Research Center, Hampton, Va.; Ames Research Center, Moffett Field, Calif.; Lewis Research Center, Cleveland, Ohio; and Flight Research Center, Edwards, Calif.

OFFICE OF LIFE SCIENCES PROGRAMS

In a report (see app. K) submitted on January 25, 1960, to Administrator Glennan, the NASA Bioscience Advisory Committee recommended organization of an Office of Life Sciences Programs. Among the committee's observations:

Somewhat paradoxically, NASA, which does have a clearly defined mission to put and maintain men in space, has essentially no existing capability for studying the biological and medical problems involved.

On March 1, 1960, an Office of Life Sciences Programs was established in headquarters to plan, organize, and operate a program of research and development in the biomedical aspects of space flight and space environment and to study possibilities of life existing elsewhere than on earth. The Office will direct research in biotechnology (integration of men and machines), space medical and behavioral sciences, and space biology carried out in NASA research centers and by contracts with other Government agencies, universities, industry, and nonprofit institutions. The Office is developing plans for a NASA life sciences research facility. These plans will provide internal competence and assure life sciences participation and programing in concert with the NASA physical and engineering components. Life sciences aspects of Project Mercury will remain assigned to the Space Task Group of Goddard Space Flight Center.

OFFICE FOR THE UNITED NATIONS CONFERENCE ESTABLISHED

The Office for the United Nations Conference was established on January 29, 1960, to plan, direct, and coordinate U.S. participation in an International Conference on the Peaceful Uses of Outer Space,

tentatively scheduled for the fall of 1961. Events leading to its creation are described in chapter 9, "International Programs," page 72. The new Office reports directly to the NASA Administrator.

OFFICE OF ASSOCIATE ADMINISTRATOR REORGANIZED

Two staff offices, one for program analysis and control and one for reliability and systems evaluation, were established in the Office of the Associate Administrator on January 1 and March 10, respectively. They review and evaluate NASA activities in terms of vehicle reliability, program balance, and progress toward established objectives.

GEORGE C. MARSHALL SPACE FLIGHT CENTER ESTABLISHED

Soldier and statesman honored

By Executive Order, March 15, 1960, the President designated NASA facilities at Redstone Arsenal, Huntsville, Ala., as the George C. Marshall Space Flight Center. This action honored the late General of the Army who served during World War II as Army Chief of Staff and later as Secretary of Defense and Secretary of State. The center will comprise the former Development Operations Division, Army Ballistic Missile Agency, plus additional facilities and personnel needed for administration. The center, well known for its team of rocket scientists and engineers who were responsible for research, development, and launching of the first U.S. satellite (Explorer I) on January 31, 1958, is developing the 1.5-million-pound-thrust Saturn launch vehicle.

NASA begins technical direction of Saturn

Under a memorandum of understanding, endorsed by the NASA Associate Administrator and the Director of Defense Research and Engineering, DOD, NASA began technical direction of Project Saturn on November 18, 1959. Other provisions of the agreement, which is effective until the formal transfer of Marshall on July 1, 1960, are:

(1) A Saturn Committee, consisting of representatives of NASA, the Advanced Research Project Agency (ARPA), the Army Ballistic Missile Agency, and the Department of the Air Force, will assist and advise the NASA Administrator.

(2) The Director of ARPA will continue administration of the project, conducting it through existing ARPA task orders.

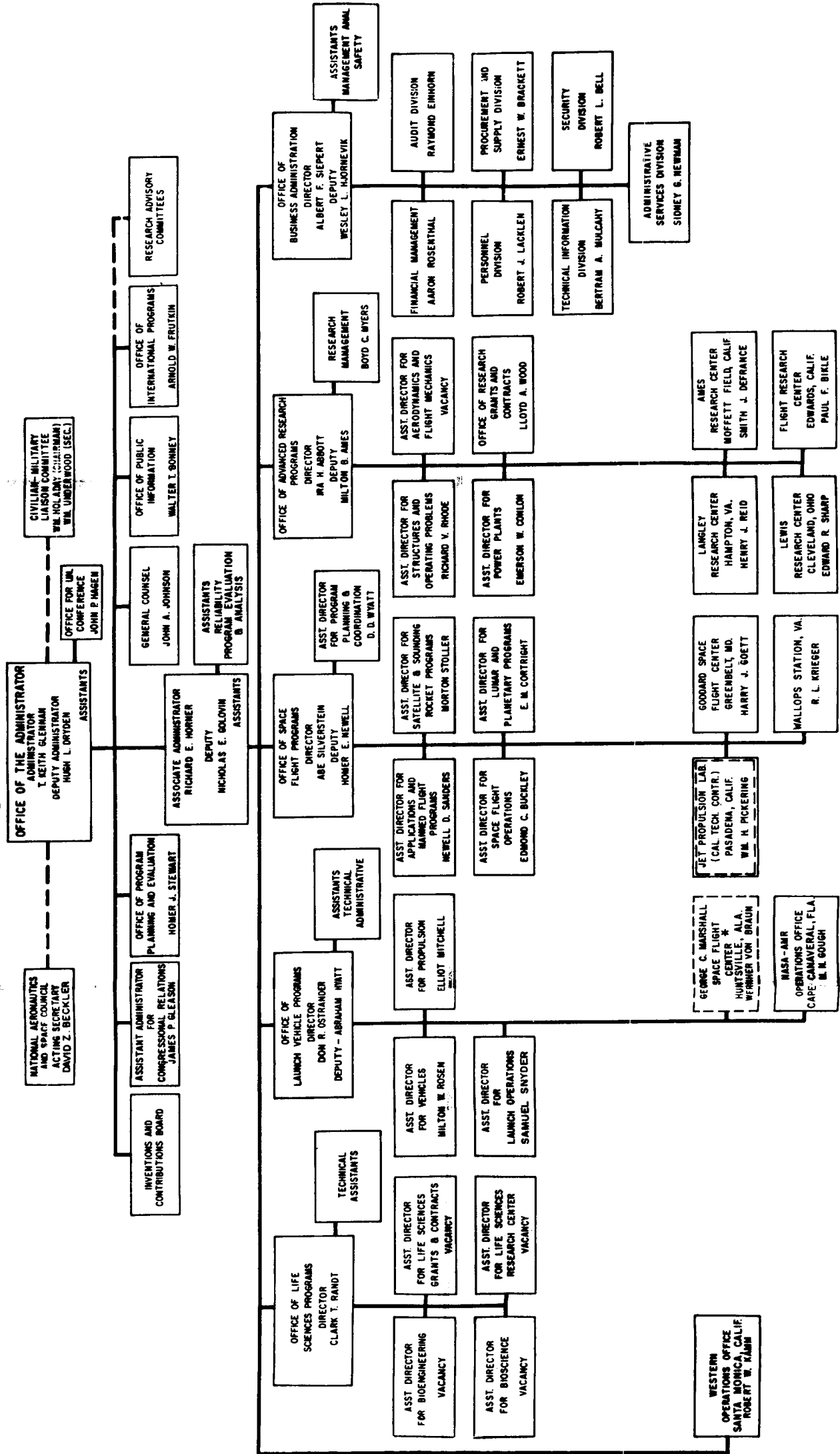
(3) The Director, Defense Research and Engineering, will provide the NASA Administrator a statement of military interest as a guide in technical direction.

(4) Public information activities will be coordinated.

Marshall functions after transfer

When formally transferred to NASA, Marshall will have major field responsibility for launch vehicle design, development, and firing. Thus, its tasks will include not only the Saturn project, but also development of the Centaur launch vehicle, adaptation of the Air Force Thor-Agena B and Atlas-Agena B boosters to NASA missions, and technical direction of the F-1, a 1.5-million-pound-thrust single-chamber engine under development by Rocketdyne Division of North American Aviation, Inc. In addition, the center will engage in advanced rocket engine and propulsion studies.

ORGANIZATION CHART NATIONAL AERONAUTICS AND SPACE ADMINISTRATION April 1, 1960



* TRANSFER FROM U.S. ARMY
PENDING TO BE EFFECTIVE
JULY 1, 1960.

SPACE FLIGHT CENTERS SPECIALIZE

Acquisition of the Marshall Center has made possible the following division of primary space flight responsibilities:

(1) *Marshall*.—Design and development of launch vehicles, and supervision of NASA launch operations at the Atlantic and Pacific Missile Ranges.

(2) *Goddard*.—Project Mercury and earth satellite programs.

(3) *JPL*.—Mission planning and development of payloads for lunar and interplanetary exploration.

STRUCTURE AND FUNCTIONS

The organization of NASA on April 1, 1960, is shown in the accompanying chart. Functions of some Headquarters offices have been described in the foregoing "Organizational Development" and those of others are apparent from their titles or from those of their subdivisions. Memberships of the research advisory committees, which assist the Administrator in formulating programs of study in aeronautical and space fields, are given in appendix J. Activities of field installations during the reporting period, summarized below, serve to highlight their functions.

LANGLEY RESEARCH CENTER

The center engages primarily in research in aerodynamics, fluid mechanics, structural and materials applications, and launching problems caused by heating and flow of air and rarified gases.

During the period, Langley experimented with inflatable spacecraft; vertical and short takeoff and landing (V/STOL) aircraft; supersonic air transports; and simulated orbital rendezvous of space vehicles. Langley was also participating in development of the Scout launch vehicle, the passive communications satellite (Project Echo), a micrometeoroid satellite experiment, and Project Mercury, the first step in manned space flight. Langley is responsible for establishing the Mercury tracking network, which will maintain communication with the Mercury capsule, and for supporting the Space Task Group in training the astronauts to control the capsule; checking reliability of the capsule systems; testing its heat shield, noise environment, and aerodynamic characteristics; and studying methods to minimize capsule landing shock.

AMES RESEARCH CENTER

The center is responsible for research, both basic and applied, primarily in hypervelocity dynamics and flight mechanics—including heat transfer, flow phenomena, and stabilization, control, and orientation of spacecraft. Ames also engages in selected research studies relating to fluid mechanics, stability and control, and vibration and flutter. Among research and development projects during the period were: orbital attitude stabilization of the meteorological satellite (Project Nimbus); attitude control systems, optical sensors, and power supplies for an orbiting astronomical observatory; defining of the dynamic stability of the Mercury capsule; entry, hypersonic, and supersonic aerodynamics of space vehicles; V/STOL

aircraft; missiles and supersonic aircraft; and effects of micrometeoroid impacts on materials. In addition, studies were made on human capability for control, guidance, and navigation of multistage launch vehicles.

LEWIS RESEARCH CENTER

The center's research is primarily in propulsion, power generation, materials, and aerodynamics of spacecraft for lunar and deep space missions. It utilizes the Plum Brook installation at Sandusky, Ohio, for nuclear systems research and certain rocket system studies including gas generator systems, turbopumps, fuel systems, and dynamics of complete spacecraft systems. During this period, Lewis operated several prototype ion and plasma rocket engines to determine problems, to indicate the direction of research, and to test applicability of research data. To improve liquid-fueled rockets, the center conducted advanced research on nozzles, fuels (hydrogen-fluorine, hydrogen-oxygen), ignition and combustion of propellants, and on complete rocket engine systems.

FLIGHT RESEARCH CENTER

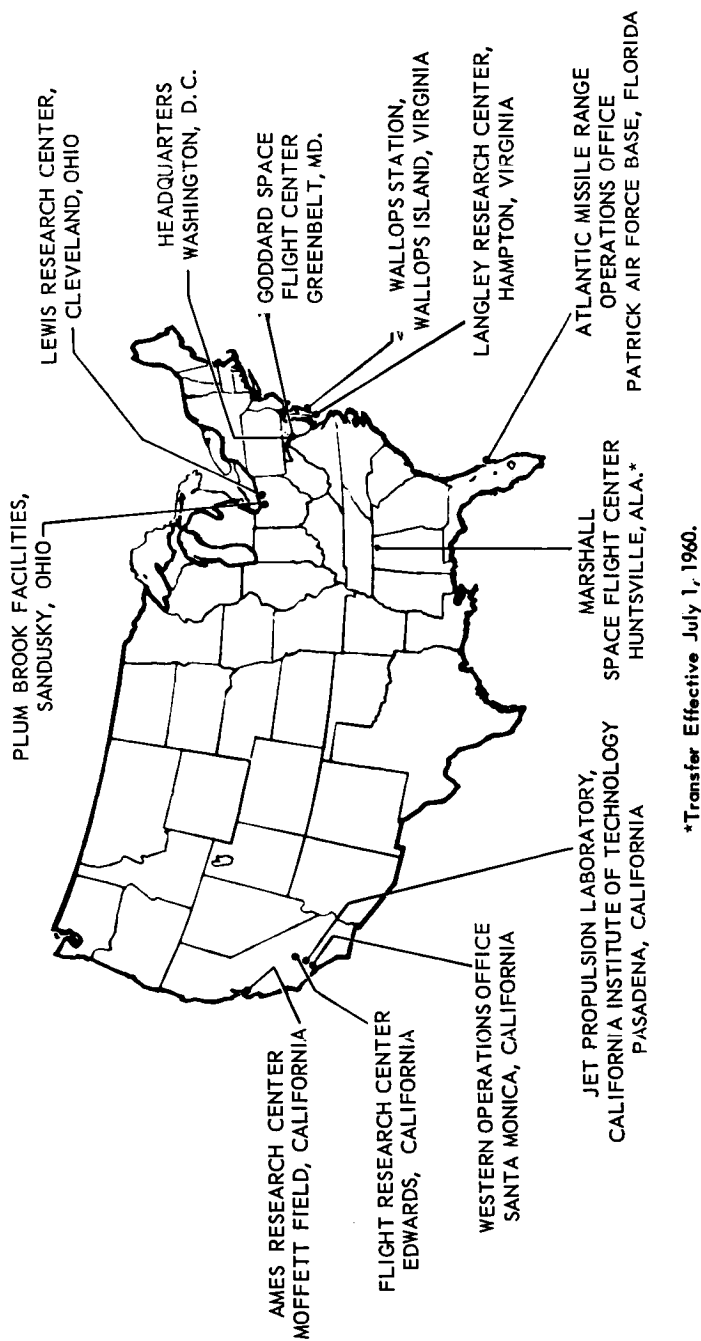
The center's primary mission is research in high-speed aircraft flight stability and control, handling qualities, performance, loads, propulsion aerodynamics, and aerodynamic heating. The center is responsible for operating and testing the X-15 research airplanes that are expected to reach velocities of 4,000 miles per hour and altitudes near 50 miles. One X-15 airplane has been accepted from the contractor, and NASA pilots are making familiarization flights prior to utilizing it in its design mission—research in high altitude, hypersonic, manned flight, with emphasis on such areas as vehicle control, aerodynamic heating, and the effects of weightlessness on the pilots. Two other craft will be transferred upon satisfactory completion of the contractor's demonstration flights.

GEORGE C. MARSHALL SPACE FLIGHT CENTER

The center will be primarily responsible for research and development of large launch vehicle systems, including development of guidance systems, testing, and modification to assure their reliable operation. Marshall will also be responsible for launching NASA space vehicles and for research and development in such areas as advanced propulsion and guidance systems.

ATLANTIC MISSILE RANGE (AMR) OPERATIONS OFFICE

This office coordinates and schedules use of AMR facilities for NASA programs. Successful NASA launchings from AMR during the period include the Explorer VII and Tiros I satellites and the Pioneer V space probe. (See ch. 3, "Experimental Missions," pp. 9-27.)



Locations of NASA Installations.

WESTERN OPERATIONS OFFICE

In addition to providing administrative and management support to NASA activities west of Denver, Colo., this Office provides liaison with industry, scientific institutions, and universities in the Far West. It furnishes technical supervision, contract administration, legal and patent counsel, security, auditing, information, and fiscal management services to the Ames and Flight Research Centers and is responsible for administering the Jet Propulsion Laboratory contract. It has been active in the Delta, Centaur, Atlas-Agena B, and Thor-Agena B launch vehicle development programs and in the F-1 rocket engine development program.

GODDARD SPACE FLIGHT CENTER

The center has primary responsibility for earth satellite, geophysical sounding rocket, and Project Mercury programs. Its functions include mission planning, development of payloads and instrumentation, and analysis of data from satellites and sounding rockets. During the period, Goddard developed, prepared programs for, and analyzed data from such operational missions as the Explorer VII and Tiros I satellites and the Pioneer V space probe; directed sounding rocket programs carried out at Wallops Station, Va.; was expanding the Minitrack tracking and data acquisition network, preparing to operate the Mercury network (see ch. 10, pp. 76-77) and made substantial progress in Project Mercury (see ch. 5, pp. 36-48).

WALLOPS STATION

The functional activities of Wallops Station are described in chapter 10, "Tracking and Data Acquisition," page 77.

JET PROPULSION LABORATORY (JPL)

A Government-owned facility operated for NASA under contract by the California Institute of Technology, JPL has been assigned responsibility for mission planning and development of spacecraft for lunar and interplanetary exploration. In performing its mission, JPL worked with industry on the Atlas-Agena B and Atlas-Centaur launch vehicle programs, conducted theoretical studies in space sciences, developed instruments for gathering space data, and assisted the scientific community in integrating experiments into the lunar and interplanetary flight programs. As technical director and contract monitor for NASA's deep space tracking network, JPL supervised installation of a transmitting system at Goldstone, Calif., and planned receiving systems for oversea stations.

JPL also conducted advanced research and development in physics, gas dynamics, propulsion, materials, and electronics. In addition, it directed development of the Sergeant weapon system for the Army and tested several Army and Air Force missile models in wind tunnels.

NASA RELATIONS WITH OTHER GOVERNMENT AGENCIES

Work performed by NASA in the technologies of aeronautics and space is interrelated with many activities taking place in other Government organizations with which NASA cooperates and coordinates its programs. For example, the SNAP-8 project, mentioned elsewhere in this report, is a joint endeavor of NASA and the Atomic Energy Commission; TIROS I, the weather satellite experiment, involved NASA cooperation with the Weather Bureau of the Department of Commerce and a number of other Government agencies, military and civilian.

Agencies and fields in which there are coordinated and cooperative activities are listed in NASA's "Second Semiannual Report—April 1–September 30, 1959."

CHAPTER 17

PERSONNEL

COMPOSITION AND GROWTH OF NASA STAFF

On March 31, 1960, NASA was staffed by 9,691 civilian employees, of which 27.5 percent were research scientists; 8 percent, research facility engineers; 8.6 percent, draftsmen, designers, and aides; 38.7 percent, trades and crafts; and 17.1 percent, professional, administrative, and clerical personnel. General schedule (GS) employees totaled 5,733; wage board (WB), 3,741; and excepted and statutory, 218. NASA employs 18 foreign scientists; the Civil Service Commission has authorized hiring of 50. The figures do not include 2,667 employees of the Jet Propulsion Laboratory (JPL), under contract to NASA, or the approximately 5,500 positions established for the George C. Marshall Space Flight Center.

NASA employment is expected to total 9,988 by June 30, 1960, excluding JPL and Marshall. This increase is primarily due to staffing of the new Goddard Space Flight Center. Distribution of personnel among organizational elements is shown in table 2.

RECRUITING, EXAMINING, AND TRAINING

RECRUITING AND EXAMINING

Recruiting remains a major problem because relatively few qualified applicants are available for NASA scientific positions. NASA seeks qualified applicants through contacts with more than 120 institutions of higher learning; advertisements in scientific journals and trade publications; and distribution of publications describing employment and training opportunities. In addition to distributing material emanating from headquarters, field centers prepare and distribute publications illustrating employment advantages at their installations.

The advent of space programs has created many new fields of science and engineering. To recruit for these new fields, NASA is issuing a nationwide examination for the recruitment and selection of scientists and engineers which evaluates and selects individual scientists and engineers on the basis of their research specialty experience rather than the academic degrees they hold—the usual method of selection in the past. This allows more flexibility in selection and a much better appraisal of the individual's qualification in terms of the new and different fields of work he will be expected to perform.

TABLE 2.—*Distribution of NASA personnel*

Location	Mar. 31, 1959		Sept. 30, 1959		Mar. 31, 1960	
	Civilian	Military	Civilian	Military	Civilian	Military
Langley ¹	3,587	13	3,877	11	3,185	12
Ames ²	1,434	16	1,434	18	1,409	17
Lewis ³	2,711	30	2,788	24	2,725	12
Goddard ⁴	296	—	467	6	1,183	10
Flight ⁵	303	4	336	2	371	2
Wallops ⁶	—	—	—	—	229	0
Marshall ⁷	—	—	—	—	26	0
AMR ⁸	—	—	—	—	12	0
Western Operations Office ⁹	—	—	—	—	32	0
Total field	8,331	63	8,902	61	9,172	53
Headquarters	354	—	446	5	519	11
Total	8,685	63	9,348	66	9,691	64

¹ Langley Research Center, Hampton, Va.² Ames Research Center, Moffett Field, Calif.³ Lewis Research Center, Cleveland, Ohio.⁴ Goddard Space Flight Center, Greenbelt, Md.⁵ Flight Research Center, Edwards, Calif.⁶ Wallops Station, Va. Formerly included with Goddard.⁷ George C. Marshall Space Flight Center, Huntsville, Ala. Transfer of personnel will not be complete until July 1, 1960.⁸ Atlantic Missile Range Operations Office, Cape Canaveral, Fla. Formerly included with Goddard.⁹ Western Operations Office, Santa Monica, Calif. Formerly included with Ames.

TRAINING PROGRAMS

NASA develops employee abilities through three formal training programs. It is planning others.

Graduate study training program

Approximately 750 employees are enrolled in graduate courses at 10 colleges and universities under the NASA graduate study training program. Employees are taking courses directly applicable to their work or to positions for which they are preparing. Tuition and fees are paid by the Government.

College cooperative system

Approximately 175 university students alternate work and study each year under NASA's college cooperative system. When the students receive their degrees, usually after 5 years, they have also worked approximately 2 years for NASA. No commitments are made, but approximately 80 percent of the students join NASA after graduation.

Apprentice program

NASA develops highly skilled craftsmen through an apprentice training program, in which 367 employees are enrolled. After a minimum of 4 years of classwork and on-the-job training, personnel receive journeymen's certificates approved by the U.S. Department of Labor and accredited by the State in which the training is given.

HIGH SCHOOL LIAISON

Approximately 200,000 copies of 4 booklets on aeronautics and space, written to appeal to high school science students, were distributed by NASA during the past 6 months through the National Science Teachers Association and the National Aviation Education

Council. In addition, NASA filled numerous individual requests for the publications and replied to many inquiries concerning educational prerequisites for careers in aeronautics and space.

Provision of the booklets to high schools conforms with the direction for wide dissemination of information set forth in the National Aeronautics and Space Act of 1958 and may motivate potential university science students to favor NASA employment after college graduation.

EMPLOYEES HONORED

NASA staff members won three national awards for Government service during the period:

Hugh L. Dryden, Associate Administrator, received the President's Award for Distinguished Federal Civilian Service, the highest honor bestowed on career civil servants. Dr. Dryden was cited for "scientific and administrative leadership in planning and organizing American space exploration."

Maxime A. Faget, Chief, Flight Systems Division, Space Task Group, received the Arthur S. Flemming award of the Junior Chamber of Commerce. This award is presented annually to 10 outstanding Government personnel 21 to 40 years of age.

Eugene S. Love, Assistant Chief of the Aerophysics Division, Langley Research Center, was named by the National Civil Service League as one of the 10 top career employees in the Federal Government. The league annually gives such awards on the basis of "competence, character, and achievement as representing the highest standards in the career civil service."

CHAPTER 18

OTHER ACTIVITIES

NEW AND CONTINUING WORK

This chapter gives developments in a variety of continuing and new NASA activities during the period. Included are details of (1) NASA procurement and contracting; (2) the patent program; (3) inventions and contributions; (4) new construction and equipment at NASA centers and launching sites; and (5) activities in the dissemination of public and technical information.

PROCUREMENT AND CONTRACTING

REALIGNMENT IN ORGANIZATION

The essential characteristic of the NASA procurement organization is a system of decentralized operations under central policy direction and guidance of NASA headquarters. With some exceptions—notably contracts for special programs and projects initiated by the Office of the Administrator—purchases and contracts are made by procurement personnel at the field centers or field offices.

The Procurement and Supply Division at NASA headquarters has the responsibility for developing policies and procedures, coordinating procurement and supply activities, and reviewing and approving major contracts (generally negotiated contracts in excess of \$100,000). The Division also evaluates the performance of all field procurement offices, and provides procurement assistance to field personnel in such specialized areas as transportation and traffic management, utility services, and contracts with instrumentalities of foreign governments.

Decentralization progress

During the period, a procurement group was organized at the Goddard Space Flight Center and delegated authority to negotiate and award contracts in support of the Goddard mission. In addition, the newly organized Western Operations Office at Santa Monica, Calif., was delegated authority to administer contracts in the area located at or west of Denver, including the contract between NASA and the California Institute of Technology for operating the Jet Propulsion Laboratory, previously administered by the Los Angeles Ordinance District. On March 28, 1960, a procurement office was organized at the George C. Marshall Space Flight Center, Huntsville, Ala. It will be responsible for procurement and contracting functions in support of the research and development effort of the Marshall Center. Agreement was reached between NASA and the Army Ordinance Missile Command for continuation of procurement and supply support of Marshall through June 30, 1960.

Small business program

In furtherance of the NASA small business program, specialists at each NASA procurement office, working closely with representatives of the Small Business Administration, screen proposed procurements to determine whether the work is suitable for small business participation. Along with NASA contracting officers, they also review the larger research and development contracts to ascertain subcontracting opportunities for small business concerns. During calendar year 1959, NASA awarded contracts totaling \$25,195,000 to small business firms, about 18 percent of the dollar value of procurement awarded directly to business firms.

Types of contracts

NASA usually contracts for supplies and services, including construction, by advertising for competitive bids and awarding a fixed-price contract to the lowest responsible bidder. Research and development contracts, on the other hand, are usually awarded by negotiation, since it is seldom possible to formulate precise specifications upon which prospective contractors can bid against one another.

NASA seeks and encourages wide competition for research and development projects. It distributes requests for proposals on such work to all known competent sources. The detailed technical and cost proposals submitted are evaluated by both technical and procurement staffs to determine the best overall proposal. Research and development contracts awarded during the report period are shown in appendix M.

Cooperative procurement agreements

NASA and the Department of Defense have a number of agreements for cooperative administration of contracts. The military department having jurisdiction over a plant working on a NASA contract may provide NASA with contract administration, audit, and other services as required.

Procurement regulations promulgated

During this period, NASA issued procurement regulations on the following subjects: Policies and procedures relating to advertised and negotiated procurement, simplified methods of making small purchases, revisions to existing procedures in the selection of sources for research and development contracts in excess of \$1 million, and bonds and insurance. Progress was made in drafting procurement regulations for foreign purchases, contract clauses and forms, and Federal, State, and local taxes. Because NASA and the Department of Defense are both governed by the Armed Services Procurement Act and deal largely with the same segment of industry, NASA's policy is to adopt, when practicable, procurement regulations consistent with policies and procedures in the Armed Services Procurement Regulations (ASPR).

RESEARCH GRANTS AND CONTRACTS

Sixty-eight awards

NASA was considering 297 research proposals from universities, research institutes, and industrial laboratories on October 1, 1959, and received 354 additional proposals between then and April 1, 1960. The agency awarded 68 research grants and contracts to educational

institutions and nonprofit scientific organizations, totaling \$5,135,163, during the period. Of 298 proposals declined, several stimulated or influenced subsequent competitive contracts. As the period closed, 276 research proposals were under review.

Description

Work sponsored under this program relates to space-flight development or to advanced aeronautical and space research. Although proposals are usually unsolicited, NASA encourages and carefully considers suggestions from the scientific community. The program is administered by the Office of Research Grants and Contracts, NASA headquarters. NASA scientists engaged in relevant fields review the proposals. Contracts and grants awarded or approved during the period of this report are listed by State in appendix L.

PATENT PROGRAM

PATENT WAIVER REGULATIONS

NASA Patent Waiver Regulations, first published in the Federal Register, March 5, 1959 (24 F.R. 1644-1649) and the subject of public hearings on March 18, 1959, were published October 29, 1959, in the Federal Register (24 F.R. 8777-8790). The waiver regulations set forth policy on granting waivers, and the procedure by which contractors may request the Administrator to waive rights in inventions made under NASA contracts.

ESTABLISHMENT OF PATENT COUNSEL FOR RESEARCH CENTERS

A patent counsel has been assigned to NASA's Western Operations Office and will also advise the Ames and Flight Research Centers. The counsel prepares patent applications, advises on matters pertaining to patents and inventions, and administers the patent clauses in NASA contracts. Patent counsel were previously assigned to the Langley and Lewis Research Centers and to NASA headquarters. While all field patent counsel are responsible to the General Counsel, headquarters, for professional performance, they are under jurisdiction of field installation directors.

PROTECTION OF NASA INVENTIONS

During this period, NASA employees disclosed 60 inventions to the Office of Patent Counsel. Twenty-one invention disclosures were received from NASA contractors for preparation of patent applications. Patent applications were authorized for 39 inventions; 28 applications were prepared; and 21 patents were issued to the Government.

PATENT INFRINGEMENT

One new administrative claim for patent infringement was received but was denied by NASA as being based on an invalid patent. A suit for patent infringement was filed against NASA and other Government agencies in the Court of Claims. NASA continued to investigate one infringement claim, and settlement of another is pending.

REVIEW OF PATENT APPLICATIONS

Section 305(c) of the National Aeronautics and Space Act provides for review by the Administrator of patent applications having significant utility in aeronautical and space activities. Under sections 305 (d) and (e), the Administrator has the prerogative of requesting that any patent having such significance be issued to him on behalf of the United States. In accordance with these provisions, the Commissioner of Patents transmitted to NASA 39 copies of patent applications. This substantial decrease from the 644 applications transmitted during the last report period was due to administrative arrangements with the Commissioner of Patents which permitted a more appropriate selection of applications, based on NASA contract activities. Review of these applications indicated that none involved inventions made under NASA contracts. The Administrator advised the Commissioner of Patents that he would not request that any of these patents be issued to him.

REPORTING OF INVENTIONS BY CONTRACTORS

NASA contractors must promptly furnish to the Administrator a full, written report of any inventions made in the performance of work under a contract. During the period, contractors reported 28 inventions. Of these, NASA assumed title to 21. Titles of five are being determined, and two are subject to approval of petitions for waivers of rights filed by contractors.

INVENTIONS AND CONTRIBUTIONS

FUNCTIONS OF THE INVENTIONS AND CONTRIBUTIONS BOARD

The Inventions and Contributions Board considers petitions from NASA contractors requesting waiver of U.S. patent rights for inventions made under NASA contracts, and recommends to the Administrator for or against granting them. The Board also evaluates scientific and technical contributions, and recommends to the Administrator whether monetary awards should be granted. Oral hearings are granted by the Board to petitioners for waiver of patent rights, and to applicants for awards.

The Board operates under the authority of, and in accordance with, the provisions of section 305(f) and section 306 of the National Aeronautics and Space Act of 1958. Its membership is shown in Appendix H.

CONTRIBUTIONS AWARDS

Permanent rules and regulations relating to awards for scientific and technical contribution, as required by section 306 of the act, were published on February 13 in the Federal Register (25 F.R. 1312, 1313, 1960).

During the period, the Board received 821 proposed contributions, determined 624 did not have a significant value to warrant recommendation for an award, and was evaluating 197 as the period closed.

WAIVER PETITIONS GRANTED

The first petition for waiver of rights in an invention made under a NASA contract was submitted by the Pratt & Whitney Division of United Aircraft Corp., East Hartford, Conn., on July 27, 1959. On the recommendation of the Board, the Administrator granted the waiver on August 3, 1959.

Bell Aircraft Corp., Buffalo, N.Y., submitted the second such petition on November 18, 1959. The contractor explained the commercial uses of the invention at an oral hearing before the Board on March 9, 1960. On March 16, the Board recommended to the Administrator that waiver of title be granted.

Action on the third petition for waiver of rights, received from McDonnell Aircraft Corp., St. Louis, Mo., on February 5, 1960, was pending as the period closed.

CONSTRUCTION AND EQUIPMENT

Progress in aeronautical and space technology has created a demand for new and modernized facilities. To meet this requirement, NASA is continuing its program of construction, laboratory modernization, and equipment acquisition. Expenditures during the period have totaled about \$25,500,000 exclusive of the Minitrack and Mercury tracking networks. This includes \$1,850,000 for the George C. Marshall Space Flight Center, Huntsville, Ala., which will be transferred from the Army Ballistic Missile agency to NASA effective July 1. Descriptions of new facilities completed, under construction, or planned during the period are presented below for each field installation.

LANGLEY RESEARCH CENTER, HAMPTON, VA.

Taxi strip

The center is within the grounds of Langley Air Force Base. When the Air Force recently completed a new runway extension, the center constructed at a cost of \$662,000 a connecting taxi strip, including runup and approach aprons, from its Flight Research Laboratory in order to tie into the runway system.

Central heating

NASA facilities in the east area had been heated by seven individual units. These were replaced by a central steam generation and distribution system. No building construction was required as NASA utilized space in an Air Force heating plant for installation of boilers.

Repairs

Replacements were made for cracked shafts in the fan-drive system of the 16-foot transonic wind tunnel and for component parts of equipment in the Gas Dynamics Laboratory. The rotor of the 63,333-horsepower main drive motor of the unitary plan wind tunnel was repaired.

Projects nearing completion

Construction on the following projects has reached a stage where the facilities can be partially utilized: (1) Modifications and improvements to the 19-foot pressure tunnel and to the 8-foot transonic tun-

nel; (2) a 20-inch variable Mach number facility; (3) an increased power supply for the structures research laboratory; (4) a hypersonic physics test area to analyze abilities of materials to withstand high temperatures and other environmental factors; and (5) a data reduction center containing high-speed electronic computing equipment to facilitate analysis of research data.

AMES RESEARCH CENTER, MOFFETT FIELD, CALIF.

A 3.5-foot hypersonic wind tunnel

A 3.5-foot hypersonic wind tunnel (total estimated cost of which is \$11 million) is 93 percent complete and instrument calibration is scheduled for June 1, 1960. Designed primarily to study pressures and temperatures in steady level flight at hypersonic speeds, the tunnel can generate pressures to 3,000 pounds per square inch and temperatures to 3,000° F. Experiments with scaled duplications of aircraft structural components will evaluate aerodynamic effects due to structural distortions.

Helium wind tunnel

A 12-inch hypersonic helium wind tunnel is 90 percent complete, with instrument calibration scheduled for June 15, 1960. The tunnel is of the blow-down type (which releases helium under high pressure to achieve high velocities) with provision to recover the helium after each run. It will simulate speeds from Mach 12²³ to Mach 20 up to 4 minutes, furnishing detailed test data of extended duration. Aggregate cost will be about \$1,585,000.

Flight Research Laboratory

Extensions to the Flight Research Laboratory, which will cost about \$990,000, are approximately 85 percent complete. This project also includes construction of a 3° and a 5° of motion simulator for study of human and automatic control problems in space flights and atmosphere flights.

Hypervelocity Research Laboratory

Approximately 80 percent of a Hypervelocity Research Laboratory, total estimated cost \$1,145,000, has been constructed. Problems of high-temperature gases, magnetohydrodynamic effects of flow characteristics of fluids, interaction between high-velocity particles, and matter in solid and liquid state will be investigated in this laboratory.

Mass-transfer cooling and aerodynamics facility

Designs and specifications are being drawn for a mass-transfer cooling and aerodynamics facility, estimated cost of which is \$4 million. Construction is scheduled to begin in July 1960. This electric-arc heated wind tunnel will simulate heating rates (18,000° F.) and air energy levels encountered during entry for as long as 10 minutes, permitting detailed study of mass-transfer (ablating) cooling systems.

Data reduction center

Engineering and design of a data reduction center building are 50 percent complete. This building's 43,500 square feet of floor space

²³ Mach 1 is the speed of sound, 1,117 feet per second at 59° F.

will house a large capacity, high-speed digital computer system for reducing research data and for solving complex theoretical problems. Total estimated cost of this center, including equipment, is \$2,350,000.

LEWIS RESEARCH CENTER, CLEVELAND, OHIO (INCLUDING PLUM BROOK FACILITIES, SANDUSKY, OHIO)

Nuclear facilities

Modifications to the Component Research Facility for Nuclear Propulsion are 90 percent complete. This facility, part of the nuclear test reactor located in Plum Brook, will be used for detailed study of problems associated with nuclear rocket propulsion systems for long space journeys; for reactor and shielding problems associated with the generating plant for electric propulsion and auxiliary power equipment; and for allied problems of nuclear rocket, radiation, and fluid flow. An almost-complete addition to the materials and stresses building will house a zero-power reactor which will be used for experiments concerning critical points of nuclear propulsion activities, measurement of basic properties of neutron sources and reactivity effects, and research in self-shielding.

Propulsion Systems Laboratory

Modifications to the Propulsion Systems Laboratory for testing high-energy rocket engines for space propulsion are essentially complete.

Rocket Systems Research Facility

About 74 percent of the Rocket Systems Research Facility located at Plum Brook has been constructed. It will be used for studies of propellant control and pumping, multistage hydrogen pumps, and turbopumps; and tests on large-scale models and instrumentation for research vibration tests.

Supersonic wind tunnel

An air heater for the 10 by 10 foot supersonic wind tunnel is 45 percent complete. Its jet of hot compressed air, simulating the exhaust blast of a rocket engine model, will eliminate the need for heating the tunnel's entire air supply. The heater makes possible studies of the interaction of the rocket jet and external flow; and increases the tunnel's simulated altitude from 150,000 feet to 250,000 feet.

Hypersonic Missile Propulsion Facility

Sixty percent of a Hypersonic Missile Propulsion Facility is complete. Its 2-square-foot test section, filled with super-heated gas (10,000° F. to 15,000° F.), will be used in aerodynamic research and preliminary studies of jet propulsion systems housing electric-arc or ionized-gas streams.

Materials Research Laboratory

Modification of the Materials Research Laboratory, to include creep and tensile testing machines to study the mechanical properties of materials at cryogenic (intensely cold) temperatures and vacuum-metallizing equipment for the development and application of coatings for refractory materials is 89 percent complete. Total cost, including equipment, is \$2,120,000.

Rocket engine research facility

The high energy rocket engine research facility, 18 percent complete, consists of three new test cells for studies of new high-energy rocket-propellant systems. One cell, at Lewis, contains three 5,000-pound thrust capacity test stands for horizontally firing engines utilizing non-toxic propellants. Two, at Plum Brook, are for research with toxic propellants, such as fluorine. Total cost, including equipment, is \$615,000.

Contemplated construction

Major projects in the design stage are: an ion and plasma jet facility for large-scale research on electric propulsion systems; a zero-power reactor (see "Nuclear Facilities," above), to be installed in the component research facility for nuclear propulsion for preliminary testing of materials before they are radiated in the powerful Plum Brook reactor; and an inpile loop for the same facility to observe heat transfer and flow of heat-resistant materials under radiation.

FLIGHT RESEARCH CENTER, EDWARDS, CALIF.

X-15 research airplane facilities

Installation of analog computing equipment to operate the X-15 flight guidance simulator is well underway. The equipment and simulator are scheduled to be delivered by July 1960. Aggregate estimated cost of the computer equipment is \$350,000. A terminal guidance facility, providing a microwave data link to transmit radar data required during X-15 flights, is being installed jointly by the Air Force and NASA. Existing buildings will be modified to house these facilities.

Test stand for F-1

A test stand for the 1.5-million-pound-thrust rocket engine, constructed for NASA by the Air Force at an estimated cost of \$15 million, is approximately 60 percent complete. The Air Force is also constructing a 2,000-ton liquid-oxygen storage and transfer facility for the test stand, and funds in the amount of \$1,340,220 will be furnished to the Air Force by NASA.

JET PROPULSION LABORATORY, PASADENA, CALIF.

Goldstone transmitter completed

The Goldstone, Calif., transmitter was constructed at a cost of \$1,005,000. The facility consists of a 10-kilowatt transmitter, an 85-foot antenna, other electronic equipment, a laboratory, and an office. Goldstone previously had only a receiving system. The Goldstone station is the first of NASA's three-station Deep Space network. (See ch. 10, "Tracking and Data Acquisition," p. 76.)

Other projects

Currently under design are:

- (1) A substation and transformer bank for use in the south area of JPL to provide power for facilities authorized in fiscal year 1959.

- (2) An addition to guidance laboratory 161—46,000 square feet of laboratory and conference space for the research and development divisions.

(3) An addition to administrative services building—15,000 square feet for purchasing, accounting, IBM, and stores activities.

(4) A plant services engineering and shop building—16,000 square feet for drafting room, offices, mechanical and electrical shops.

(5) A vehicle assembly building and environmental (testing) laboratory—37,500 square feet of open hangar space with laboratory, office, and workshop areas.

(6) A reports and periodicals building—17,000 square feet of administrative, workshop, and laboratory space.

(7) Utilities for south area to accommodate construction authorized in fiscal year 1959.

(8) Utilities in new area (60 acres) to accommodate construction of facilities for solid and liquid propellant divisions authorized in fiscal year 1959.

(9) Solid-propellant hazardous-material storage magazines, test cell and control building, and processing laboratory—20 structures, ranging in size from 936 square feet to 7,450 square feet, in the new area (60 acres).

(10) Liquid propellant test cell and control building—in new area (60 acres).

GODDARD SPACE FLIGHT CENTER, GREENBELT, MD.

Personnel of the Goddard Space Flight Center are currently utilizing borrowed facilities in the District of Columbia. A permanent installation for the center is being constructed at Greenbelt, Md., on land acquired from the Government's Agricultural Experiment Station. Progress on and contemplated use of the six planned Goddard buildings are described below.

Building No. 1

This space projects building, which is 70 percent complete, will have computer equipment and the technical library, and will house administrative, scientific, and technical personnel.

Building No. 2

This research projects laboratory, which will be used by a portion of the space sciences and satellite applications group, is also 70 percent complete.

Building No. 3

Construction is 20 percent complete on the central flight control and range operations building which will house the Mercury and Minitrack control centers.

Building group No. 4

Plans and specifications have been drawn for the central powerplant and service shops, comprising the boiler room, central air conditioning and refrigeration, maintenance shops, and storage.

Buildings Nos. 5 and 6

Designs are being drawn for the instrument construction and installation laboratory and the space sciences laboratory. The former will be used for instrument assembly and the latter by the divisions of the space sciences and satellite applications group.

WALLOPS STATION, WALLOPS ISLAND, VA.

Launch facilities

Facilities for the Scout launch vehicle including launch pads, tower, blockhouse, terminal buildings, a firefighting water deluge system, and power and communication systems are 90 percent complete.



New launching tower, constructed for the Scout vehicle, is checked out at Wallops Station with a dummy rocket.

Aerobee sounding rocket launch facilities have been constructed and already utilized. Launch instrumentation has been improved. The Scout system is being checked out with a dummy vehicle. Total cost of these facilities is estimated at \$1,923,000.

Causeway

The causeway and bridge between Wallops Island and the mainland is 80 percent complete and is in use. Surfacing of the roadway is in progress. Cost of the causeway is estimated at \$1,467,000.

Erosion control

The erosion control project is nearing completion.

Other projects

Modification of the administration building and hangar, and the construction of a telemetry building, a command-destruct building, and several small structures are 75 percent complete. These projects are estimated to total about \$1,500,000.

Radar

A building, tower, and 60-foot antenna have been constructed for the high precision tracking radar on the mainland.

MARSHALL SPACE FLIGHT CENTER, HUNTSVILLE, ALA. ²⁴

All construction at Marshall was in support of Project Saturn, the development of a clustered 1.5-million-pound-thrust launch vehicle. The east static test tower was modified at a total cost of \$1,020,000 to test the Saturn. Various fabrication and checkout buildings were modified. Roadways in the center's industrial area were strengthened and obstructions removed to facilitate intra-area transport of Saturn.

The designs for the loading site on the Tennessee River and for road modification between the test tower and the loading site were made, and construction bids invited. These facilities will enable the Saturn vehicle to be transported by barge between Marshall and Cape Canaveral, Fla., via the Tennessee River, Mississippi River, Gulf of Mexico, and Atlantic Ocean. Other major projects were an addition to the structures and mechanics laboratory to house a vibrator to test component parts of launch vehicles and the modification of the fuel test area which was 30 percent complete.

AMR, CAPE CANAVERAL, FLA.

The blockhouse for the Saturn test firings, estimated cost \$1,028,000, is about 90 percent complete; and the launch pad complex, estimated cost \$4,767,000, about 25 percent complete. Under design are allied facilities consisting of the unloading site and the auxiliary support building. Preparation of a site and bypass road for Saturn is in process. Estimated expenditure is \$314,000. Modification of hangar S in support of Project Mercury to provide special shops and laboratories, estimated to cost \$123,500, is about 75 percent complete. Construction of tracking and equipment storage buildings to support the Delta project are in progress.

TRACKING AND DATA ACQUISITION STATIONS

NASA's worldwide tracking and data acquisition networks are described in chapter 10, pages 73-79.

²⁴ Transfer to NASA effective July 1, 1960.

Minitrack

The new Fort Myers, Fla., station became operational during the period. The 136-megacycle antennas, which will replace the 108-megacycle antenna assigned to Minitrack during IGY, have been installed at the Blossom Point, Md., station. Four new stations are being constructed at Fairbanks, Alaska; Winkfield, England; St. Johns, Newfoundland; and East Grand Forks, Minn. All are expected to be operational by late 1960.

Mercury

Construction is in progress at Cape Canaveral,²⁵ Grand Canary Island, and another island in the Atlantic. A construction contract is being negotiated for the station in east Africa. Designs and specifications are being drawn for the other facilities. The Mercury network is scheduled to become operational in early 1961.

Deep Space

The transmitting system for the Goldstone Station has been completed. The site selected for the deep-space station in Australia is Island Lagoon, near Woomera. Construction has begun and is scheduled to be completed in the fall of 1960. NASA has purchased the 85-foot antenna and tracking equipment for the station from the Department of Defense. As the period closed, negotiations and technical discussions with the government of the Union of South Africa for a third deep-space station were underway.

PUBLIC AND TECHNICAL INFORMATION

PUBLIC INFORMATION

Principal media

NASA furnished information on its activities through a variety of media during the period. Principally, this was done by press release to the news media—newspapers, news weeklies, radio, television, and trade and professional journals; press briefings and conferences such as those held on Explorer VII on October 13 and December 31, and on Pioneer V on March 11 and 18; contributions of NASA scientists to professional journals; addresses of NASA officials before scientific, business, and civic associations both in this country and abroad; and symposiums.

Lunar science symposium

Typical of the symposiums was that on lunar science held December 1. Four prominent scientists discussed the importance of lunar research and described plans for lunar experiments. All members of NASA's Lunar Science Group, the scientists were: Nobel Prize winner, Harold Urey, Scripps Institute of Oceanography; Thomas Gold, Cornell University; Harrison Brown, California Institute of Technology; and Robert Jastrow, Chairman of NASA's Lunar Sciences Group (membership is in app. D).

Inquiries

NASA filled a growing demand for information from individuals and organizations, both in this country and abroad. Inquiries came from such diverse sources as students, educators, publishers,

²⁵ Facilities for the Saturn launch vehicle are also being prepared.

and leaders of industry. Some of the information was for eventual use in encyclopedias and publications of other Government agencies. In addition, an average of about 100 mail requests per week for miscellaneous NASA information was received and filled during the period.

Other media

Information was also disseminated through such publications as the NASA Second Semiannual Report to the Congress, April 1, 1959—September 30, 1959; through motion picture and television productions; the NASA inspection and open house at Langley Research Center; and exhibits.

Film is honored

"Chemistry of Meteor Vaporization," an animated, live action, color film, one of several produced by NASA during the period, received several honors. The Government Interdepartmental Committee on Visual and Auditory Materials for Distribution Abroad recommended the film for possible entry in the 1960 Venice Film Festival. The Committee also recommended the film for exhibition before the organizing committee of the American Science Film Association.

Langley inspection and open house

More than 2,000 representatives of industry, Government, and the press attended the NASA inspection at Langley Research Center, Hampton, Va., October 12 through 16. Among the guests were scientific attachés of 14 foreign nations. More than 15,000 visitors attended a Langley open house, first in the Center's 40-year existence, on Saturday, October 17.

Exhibits

NASA designed and constructed 2 identical Project Mercury exhibits and 12 identical Pioneer V exhibits to show in this country and abroad. The Mercury exhibit consists of a full-size model of the Mercury capsule and 32 panels of copy, photographs, and drawings describing the Mercury program. The Pioneer V exhibit includes a life-size fiberglass model of Pioneer V with operating solar cells and a 20-foot panel of illustrations and models. The Office of International Trade Fairs (OITF), Department of Commerce, borrowed one Project Mercury exhibit for showing at a series of overseas expositions. OITF and the U.S. Information Agency also borrowed all but two of the Pioneer V exhibits for overseas presentation. The Mercury exhibit is scheduled for display at the Aerospace Medical Symposium to be held May 9 to 11 in Miami, Fla.

TECHNICAL INFORMATION

New aeronautical dictionary

The NASA Aeronautical Dictionary, defining 4,000 terms, was published during the period. The 200-page volume was prepared in response to many requests for an up-to-date dictionary to replace NASA Report No. 474, "Nomenclature for Aeronautics," last revised in 1933. The Aeronautical Dictionary may be purchased for \$1.75 from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C.

Announcement issuance now biweekly

NASA began biweekly issuance, on alternate Thursdays, of NASA Technical Publications Announcements, listing new NASA publications for which NASA is depository and distributor. The announcements are distributed principally through mailing lists. Previously, they were issued at irregular intervals.

Release of technical information

NASA released 207 unclassified and 153 new security-classified technical publications for distribution to authorized addressees. In addition, it filled 13,815 individual requests for specific documents and other technical information.

APPENDIXES

APPENDIX A

MEMBERSHIPS OF CONGRESSIONAL COMMITTEES

(October 1, 1959, through March 31, 1960)

SENATE COMMITTEE ON AERONAUTICAL AND SPACE SCIENCES

Lyndon B. Johnson, Texas, chairman	Styles Bridges, New Hampshire
Richard B. Russell, Georgia	Alexander Wiley, Wisconsin
Warren G. Magnuson, Washington	Margaret Chase Smith, Maine
Clinton P. Anderson, New Mexico	Thos. E. Martin, Iowa
Robert S. Kerr, Oklahoma	Clifford P. Case, New Jersey
Stuart Symington, Missouri	
John Stennis, Mississippi	
Stephen M. Young, Ohio	
Thomas J. Dodd, Connecticut	
Howard W. Cannon, Nevada	

HOUSE COMMITTEE ON SCIENCE AND ASTRONAUTICS

Overton Brooks, Louisiana, chairman	Joseph W. Martin, Jr., Massachusetts
John W. McCormack, Massachusetts	James G. Fulton, Pennsylvania
George P. Miller, California	Gordon L. McDonough, California
Olin E. Teague, Texas	J. Edgar Chenoweth, Colorado
Victor L. Anfuso, New York	Frank C. Osmer, Jr., New Jersey
B. F. Sisk, California	William K. Van Pelt, Wisconsin
Erwin Mitchell, Georgia	A. D. Baumhart, Jr., Ohio
James M. Quigley, Pennsylvania	Perkins Bass, New Hampshire
David M. Hall, North Carolina ¹	R. Walter Riehman, New York
Leonard G. Wolfe, Iowa	
Joseph E. Karth, Minnesota	
Ken Hechler, West Virginia	
Emilio Q. Daddario, Connecticut	
Walter H. Moeller, Ohio	
David S. King, Utah	
J. Edward Roush, Indiana	
Thomas G. Morris, New Mexico ²	

APPENDIX B

MEMBERSHIP OF THE NATIONAL AERONAUTICS AND SPACE COUNCIL

(October 1, 1959, through March 31, 1960)

President Dwight D. Eisenhower, Chairman

Christian A. Herter	Detlev W. Bronk
Secretary of State	President, National Academy
Thomas S. Gates, Jr.	of Sciences
Secretary of Defense	Alan T. Waterman
John A. McCone	Director, National Science
Chairman, Atomic Energy	Foundation
Commission	John T. Rettaliata
T. Keith Glennan	President, Illinois Institute of
Administrator, National Aeronau-	Technology, Chicago, Ill.
tics and Space Administration	(³)

Acting Secretary
Franklyn W. Phillips ⁴
David Z. Beckler ⁴

¹ Died on Jan. 29, 1960.

² Assigned Feb. 10, 1960.

³ One vacancy, member from private life.

⁴ Mr. Beckler replaced Mr. Phillips on Feb. 28, 1960.

APPENDIX C

MEMBERSHIP OF THE CIVILIAN-MILITARY LIAISON COMMITTEE

(October 1, 1959, through March 31, 1960)

William M. Holaday,⁵ Chairman

William J. Underwood, Assistant to the Chairman and Secretary

NASA MEMBERS

Hugh L. Dryden, Deputy Administrator.

Abe Silverstein, Director of Space Flight Programs.

Homer J. Stewart, Director of Program Planning and Evaluation.

Ira H. Abbott, Director of Advanced Research Programs.

NASA ALTERNATES

DeMarquis D. Wyatt, Assistant Director, Program Planning and Coordination.
Abraham Hyatt, Deputy Director, Launch Vehicle Programs.

DEPARTMENT OF DEFENSE (DOD) MEMBERS

Roy W. Johnson, OSD, Director, Advanced Research Projects Agency.⁶John B. Macauley, Deputy Director of Research and Engineering.⁷

Maj. Gen. W. W. Dick, Army, Director of Special Weapons, Office of Chief of Research and Development, Department of the Army.

Vice Adm. R. B. Pirie, Navy, Deputy Chief of Naval Operations (Air).

Brig. Gen. Homer A. Boushey, Air Force, Assistant for Advanced Technology, Deputy Chief of Staff, Development.

DOD ALTERNATES

John B. Macauley, OSD, Deputy Director of Defense Research and Engineering.⁵A. G. Waggoner, Special Assistant for Missiles and Space Operations, Office of Defense Research and Engineering.⁸

Col. Charles G. Patterson, Deputy Director of Special Weapons Office, Chief of Research and Development, Department of the Army.

Rear Adm. K. S. Masterson, Director of Guided Missiles, Office of Chief of Naval Operations.

Col. John L. Martin, Jr., Air Force, Deputy Assistant for Advanced Technology, Deputy Chief of Staff, Development.

APPENDIX D

MEMBERSHIP OF LUNAR SCIENCE GROUP

(October 1, 1959, through March 31, 1960)

Robert Jastrow, Goddard Space Flight Center, NASA, Greenbelt, Md., Chairman.

Harrison Brown, California Institute of Technology, Pasadena, Calif.

Maurice Ewing, Lamont Geological Laboratory, Palisades, N.Y.

Thomas Gold, Cornell University, Ithaca, N.Y.

A. R. Hibbs, Jet Propulsion Laboratory, NASA, Pasadena, Calif.

Joshua Lederberg, Stanford University, Department of Genetics, Stanford, Calif.

Gordon MacDonald, Goddard Space Flight Center, NASA, Greenbelt, Md.

Frank Press, California Institute of Technology, Pasadena, Calif.

Bruno Rossi, Massachusetts Institute of Technology, Cambridge, Mass.

Ernst Stuhlinger, Army Ballistic Missile Agency, Huntsville, Ala.

Harold Urey, Scripps Institute of Oceanography, University of California, La Jolla, Calif.

¹ Resigned Apr. 30, 1960.² Until Dec. 7, 1959.³ Assigned Dec. 7, 1959.

APPENDIX E

MEMBERSHIP OF SPECIAL COMMITTEE ON LIFE SCIENCES

(October 1, 1959, through March 31, 1960)

W. Randolph Lovelace II, Chairman, director of the Lovelace Foundation for Medical Education and Research, Albuquerque, N. Mex.
Brig. Gen. Donald D. Flickinger (MC), USAF, Vice Chairman, Surgeon and Assistant Deputy Commander for Research Headquarters, Air Research and Development Command, Andrews Air Force Base, Washington, D.C.
Capt. G. D. Smith, Secretary, National Aeronautics and Space Administration.

MEMBERS

Lt. Comdr. John H. Ebersole (MC), U.S. Naval Hospital (staff), National Naval Medical Center, Bethesda, Md.
Col. Robert H. Holmes (MC), Chief, Forensic and Aviation Pathology Branch, Armed Forces Institute of Pathology, Washington, D.C.
Wright H. Langham, Los Alamos Scientific Laboratory, University of California, Los Alamos, N. Mex.
Robert B. Livingston, Director of Basic Research in Mental Health and Neurological Diseases, National Institutes of Health, Bethesda, Md.
Orr Reynolds, Director of Science, Office of the Assistant Secretary of Defense for Research and Engineering, Washington, D.C.

APPENDIX F

MEMBERSHIP OF JOINT (AEC-DOD-NASA) COMMITTEE ON
HAZARDS OF SPACE NUCLEAR SYSTEMS

(October 1, 1959, through March 31, 1960)

Robert E. English, Lewis Research Center, NASA, Cleveland, Ohio, Chairman.
Wright Langham, Los Alamos Scientific Laboratory, University of California, Los Alamos, N. Mex.
Nathan W. Snyder, Advanced Research Projects Agency, Department of Defense
Spurgeon Keeny, Office of the Special Assistant to the President for Science and Technology.

APPENDIX G

MEMBERSHIP OF
NASA COMMITTEE ON LONG RANGE STUDIES

(October 1, 1959, through March 31, 1960)

John A. Johnson, General Counsel, Chairman.
Arnold W. Frutkin, Director of International Programs.
Homer J. Stewart, Director of Program Planning and Evaluation.
Wesley J. Hjernevik, Deputy Director of Business Administration.
Jack C. Oppenheimer, Executive Secretary.

APPENDIX H

MEMBERSHIP OF
NASA INVENTIONS AND CONTRIBUTIONS BOARD

(October 1, 1959, through March 31, 1960)

Robert E. Littell, Assistant to the Director of Advanced Research Programs, Chairman.
 Paul G. Dembling, Assistant General Counsel, Vice Chairman.
 Elliott Mitchell, Assistant Director for Propulsion, Office of Launch Vehicle Programs, member.
 J. Allen Crocker, Chief, Program Coordination, Lunar and Planetary Programs, Office of Space Flight Programs, member.
 C. Guy Ferguson, Assistant Classification and Organization Officer, Personnel Division, Office of Business Administration, member.
 James A. Hootman, Secretary.

APPENDIX I

MEMBERSHIP OF THE
NASA-DOD SPACE SCIENCE COMMITTEE

(October 1, 1959, through March 31, 1960)

Homer E. Newell, Chairman, NASA Headquarters.
 John F. Clark, NASA Headquarters.
 Richard W. Davies, Jet Propulsion Laboratory, NASA, Pasadena, Calif.
 James B. Edson, Chief Scientist for Missiles, Office, Assistant Chief of Staff Intelligence, Department of the Army, Washington, D.C.
 Herbert Friedman, Superintendent, Atmosphere and Astrophysics Division, Naval Research Laboratory, Washington, D.C.
 John T. Holloway, Chief, Physical Sciences, Office of the Director of Defense, Research and Engineering, Washington, D.C.
 Geoffrey Keller, Program Director for Astronomy, National Science Foundation, Washington, D.C.
 Frank C. Hoyt, Advanced Research Projects Division, Institute for Defense Analyses, Washington, D.C.
 W. J. O'Sullivan, Jr., Langley Research Center, NASA, Hampton, Va.
 John W. Townsend, Jr., Goddard Space Flight Center, NASA, Greenbelt, Md.
 Stanley M. Greenfield, scientific adviser, Directorate of Research and Development, Office, Deputy Chief of Staff, Development, Department of the Air Force, Washington, D.C.

APPENDIX J

NASA RESEARCH ADVISORY COMMITTEES

(As of March 31, 1960)

	Page
Committee on Fluid Mechanics	147
Committee on Aircraft Aerodynamics	147
Committee on Missile and Spacecraft Aerodynamics	148
Committee on Control, Guidance, and Navigation	148
Committee on Chemical Energy Processes	149
Committee on Nuclear Energy Processes	149
Committee on Mechanical Power Plant Systems	150
Committee on Electrical Power Plant Systems	150
Committee on Structural Loads	151
Committee on Structural Design	152
Committee on Structural Dynamics	152
Committee on Materials	153
Committee on Aircraft Operating Problems	153

RESEARCH ADVISORY COMMITTEE ON FLUID MECHANICS

- William R. Sears, Chairman, head Graduate School of Aeronautical Engineering, Cornell University, Ithaca, N.Y.
- Keith Boyer, Associate J Division Leader, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.
- Antonio Ferri, professor of aeronautical engineering and director of Aerodynamics laboratory, Polytechnic Institute of Brooklyn, Freeport, N.Y.
- Wayland C. Griffith, assistant director of research, Missiles and Space Division, Lockheed Aircraft Corp., Sunnyvale, Calif.
- A. Hertzberg, head, aerodynamic research department, Cornell Aeronautical Laboratory, Inc., Buffalo, N.Y.
- Otto Laporte, professor of physics, University of Michigan, Ann Arbor, Mich.
- Hans W. Liepmann, professor of aeronautics, California Institute of Technology, Pasadena, Calif.
- C. C. Lin, School of Mathematics, the Institute for Advanced Study, Princeton, N.J.
- Robert W. Perry, chief, reentry simulation laboratory, Republic Aviation Corp., Farmingdale, Long Island, N.Y.
- Harry E. Petschek, principal research scientist, Avco Research Laboratory, Avco Manufacturing Corp., Everett, Mass.
- S. A. Schaaf, chairman for aeronautical sciences, College of Engineering, University of California, Berkeley, Calif.
- Joseph Sternberg, Chief, Exterior Ballistic Laboratory, Ballistic Research Laboratories, Aberdeen Proving Ground, Md.
- H. H. Kurzweg, Associate Technical Director for Aeroballistic Research, U.S. Naval Ordnance Laboratory, White Oak, Silver Spring, Md.
- Carl Kaplan, Chief Scientist, Air Force Office of Scientific Research, SRR, Washington, D.C.
- G. B. Schubauer, Chief, Fluid Mechanics Section, National Bureau of Standards, Washington, D.C.

NASA staff representatives

- Clinton E. Brown, Langley Research Center.
- Robert T. Jones, Ames Research Center.
- Wolfgang E. Moeckel, Lewis Research Center.
- John Laufer, Jet Propulsion Laboratory.
- Alfred Gessow, Headquarters, Secretary.

RESEARCH ADVISORY COMMITTEE FOR AIRCRAFT AERODYNAMICS

- R. Richard Heppe, Chairman, chief preliminary design engineer, California Division, Lockheed Aircraft Corp., Burbank, Calif.
- L. L. Douglas, vice president, engineering, Vertol Aircraft Corp., Morton, Pa.
- Orville R. Dunn, assistant chief, aerodynamics section, Douglas Aircraft Co., Inc. Santa Monica, Calif.
- Alexander H. Flax, Chief Scientist, Office of the Chief of Staff, U.S. Air Force, Washington, D.C.
- Charles W. Frick, Jr., chief technical engineer, San Diego division, Convair, Division of General Dynamics Corp., San Diego, Calif.
- L. P. Greene, manager, research and development, Los Angeles division, North American Aviation, Inc., International Airport, Los Angeles, Calif.
- William T. Hamilton, chief of flight technology, Seattle division, Boeing Airplane Co., Seattle, Wash.
- Franj W. Kolk, director, equipment research, American Airlines, Inc., La Guardia Airport Station, Flushing, N.Y.
- Conrad A. Lau, chief of advanced aircraft, Chance Vought Aircraft, Inc., Dallas, Tex.
- John G. Lee, director of research, United Aircraft Corp., East Hartford, Conn.
- William J. O'Donnell, chief engineer, applied research and development, Republic Aviation Corp., Farmingdale, Long Island, N.Y.
- William M. Zarkowsky, program manager, Grumman Aircraft Engineering Corp., Bethpage, Long Island, N.Y.
- D. M. Thompson, Chief, Air Research and Development Division, Office of the Chief of Transportation, Department of the Army, Washington, D.C.
- G. L. Desmond, Airframe Design Division, Office of Assistant Chief for Research, Development, Test, and Evaluation, Bureau of Naval Weapons, Department of the Navy, Washington, D.C.
- Ezra Kotcher, technical director, directorate of advanced systems technology, Wright Air Division, Wright-Patterson Air Force Base, Ohio.

NASA staff representatives

John Stack, Langley Research Center.
 R. G. Robinson, Ames Research Center.
 Carl F. Schueller, Lewis Research Center.
 D. E. Beeler, Flight Research Center.
 A. J. Evans, Headquarters, Secretary.

RESEARCH ADVISORY COMMITTEE ON MISSILE AND SPACECRAFT AERODYNAMICS

H. Guyford Stever, Chairman, associate dean of engineering, Massachusetts Institute of Technology, Cambridge, Mass.
 Mac C. Adams, deputy director, Avco Research Laboratory, Avco Manufacturing Corp., Everett, Mass.
 H. W. Bell, assistant director, Aero-Space Laboratories, Missile Division, North American Aviation, Inc., Downey, Calif.
 Seymour M. Bogdonoff, professor of aeronautical engineering and head of Gas Dynamics Laboratory, Princeton University, Princeton, N.J.
 K. J. Bossart, assistant to the vice president, engineering, Convair, Division of General Dynamics Corp., San Diego, Calif.
 George S. Graff, chief aeromechanics engineer, McDonnell Aircraft Corp., Lambert-St. Louis Municipal Airport, St. Louis, Mo.
 Robert B. Hildebrand, chief, Advanced Research Systems Section, Flight Technology Department, Aero Space Division, Boeing Airplane Co., Seattle, Wash.
 Maxwell W. Hunter, assistant chief engineer, space systems, Douglas Aircraft Co., Inc., Santa Monica, Calif.
 Otto Klima, Jr., manager, aerodynamics and space mechanics, Missile and Space Vehicle Department, General Electric Co., Philadelphia, Pa.
 C. J. Koch, Director, systems dynamics and control, the Martin Co., Baltimore, Md.
 Lester Lees, professor of aeronautics, California Institute of Technology, Pasadena Calif.
 Ronald Smelt, director, research, Missiles and Space Division, Lockheed Aircraft Corp., Sunnyvale, Calif.
 Ernst D. Geissler, director, Aeroballistics Laboratory, Development Operations Division, Army Ballistic Missile Agency, ORDAB-DA, Redstone Arsenal, Ala.
 Capt. Irvin G. Peters, U.S. Navy, astronautics programs officer, Office of Assistant Chief for Program Management, Bureau of Naval Weapons, Department of the Navy, Washington, D.C.
 Col. J. L. Martin, Jr., deputy director of advanced technology, Office of the Deputy Chief of Staff, Development, Department of the Air Force Washington, D.C.

NASA staff representatives

John Becker, Langley Research Center.
 H. Julian Allen, Ames Research Center.
 Eugene J. Manganiello, Lewis Research Center.
 Hubert M. Drake, Flight Research Center.
 M. Eimer, Jet Propulsion Laboratory.
 Ralph W. May, Headquarters, Secretary.

RESEARCH ADVISORY COMMITTEE ON CONTROL, GUIDANCE, AND NAVIGATION

Allen E. Puckett, Chairman, vice president and director of systems development laboratories, Hughes Aircraft Co., Culver City, Calif.
 Gene L. Armstrong, senior project engineer, Convair-Astronautics Division of General Dynamics Corp., San Diego, Calif.
 Rudolph Bodemuller, manager, Systems Development Section Bendix Products Division, Bendix Aviation Corp., South Bend, Ind.
 C. Stark Draper, head, Department of Aeronautics and Astronautics, Massachusetts Institute of Technology, Cambridge, Mass.
 D. B. Duncan, general operations manager, space technology operations, Aeronutronic Division of Ford Motor Co., Ford Road, Newport Beach, Calif.
 Emanuel Ethenakis, manager, navigation and control engineering, Missile and Ordnance Systems Department, General Electric Co., Philadelphia, Pa.
 H. R. Hegbar, manager, avionics and electronics, Goodyear Aircraft Corp., Akron, Ohio.
 William J. Jacobi, director, advanced systems engineering, Litton Industries, Beverly Hills, Calif.

- Donald P. Ling, director of military analysis, Bell Telephone Laboratories, Inc., Whippany, N.J.
 William T. Russell, director, electromechanical systems laboratory, Space Technology Laboratories, Inc., Los Angeles, Calif.
 O. H. Schuck, director of research, Military Products Group, Minneapolis-Honeywell Regulator Co., Minneapolis, Minn.
 Walter Haeussermann, director, guidance and control, Development Operations Division, Army Ballistic Missile Agency, Redstone Arsenal, Ala.
 W. B. McLean, technical director, Naval Ordnance Test Station, China Lake, Calif.
 F. M. Box, U.S. Air Force, Air Force Ballistic Missile Division, Headquarters ARDC, United States Air Force, Air Force Unit Post Office, Los Angeles, Calif.

NASA staff representatives

- Leonard Sternfield, Langley Research Center.
 Howard F. Matthews, Ames Research Center.
 A. S. Boksenbom, Lewis Research Center.
 Joseph Weil, Flight Research Center.
 C. R. Gates, Jet Propulsion Laboratory.
 Bernard Maggin, headquarters, secretary.

RESEARCH ADVISORY COMMITTEE ON CHEMICAL ENERGY PROCESSES

- James A. Reid, Chairman, director of research, Phillips Petroleum Co., Bartlesville, Okla.
 David Altman, United Research Corp. of Menlo Park, 1944 University Avenue, Palo Alto, Calif.
 A. L. Antonio, vice president, Chemical Division, Aerojet-General Corp., Azusa, Calif.
 W. H. Avery, supervisor, applied research, Applied Physics Laboratory, the Johns Hopkins University, Silver Spring, Md.
 Farrington Daniels, chairman, Department of Chemistry, University of Wisconsin, Madison, Wis.
 Allen R. Deschere, general manager, Redstone Arsenal Research Division, Rohm & Haas Co., Huntsville, Ala.
 John A. Drake, 3610 Valley Meadow Road, Sherman Oaks, Calif.
 J. E. Froehlich, vice president, special projects, Alpha Corp., Richardson, Tex.
 John P. Longwell, head, special projects unit, Esso Research and Engineering Co., Linden, N.J.
 R. J. Thompson, manager of research, Rocketdyne Division, North American Aviation, Inc., Canoga Park, Calif.
 C. M. Hudson, technical assistant, Guided Missile Systems Branch, Ordnance Research and Development Division, Office of the Chief of Ordnance, Department of the Army, Washington, D.C.
 Frank I. Tanczos, assistant for supporting research missile office, Office of Assistant Chief for Research, Development, Test, and Evaluation, Bureau of Naval Weapons, Department of the Navy, Washington, D.C.
 Marc P. Dunnam, chief, Fuel and Oil Branch, Propulsion Laboratory, Wright Air Development Division, Wright-Patterson Air Force Base, Ohio.

NASA staff representatives

- W. T. Olson, Lewis Research Center.
 John I. Shafer, Jet Propulsion Laboratory.
 Harold F. Hipsher, Headquarters, Secretary.

RESEARCH ADVISORY COMMITTEE ON NUCLEAR ENERGY PROCESSES

- Walter H. Jordan, chairman, assistant director, Oak Ridge National Laboratory, Union Carbide Nuclear Co., Oak Ridge, Tenn.
 Arthur T. Biehler, Aerojet General Nucleonics, San Ramon, Calif.
 Edward A. Frieman, the James Forrestal Research Center, Princeton University, Princeton, N.J.
 Miles C. Leverett, manager, Development Laboratories, ANP Department, General Electric Co., Cincinnati, Ohio
 P.H. Miller, Jr., General Atomic Division of General Dynamics Corp., San Diego, Calif.
 Richard F. Post, Radiation Laboratory, University of California, Livermore, Calif.
 R. E. Schreiber, N division leader, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

M. A. Schultz, engineering manager, testing reactor, Westinghouse Electric Corp., Pittsburgh, Pa.
 Michael F. Valerino, associate director, Physics Department, General Nuclear Engineering Corp., Dunedin, Fla.
 Joseph Wetch, group leader, Compact Power Plant Group, Atomics International Division, North American Aviation, Inc., Canoga Park, Calif.
 Russell D. Shelton, supervisory nuclear physicist, Research Projects Laboratory, Army Ballistic Missile Agency, Redstone Arsenal, Ala.
 Capt. Edward W. Hribar, U.S. Navy, head, Aircraft Nuclear Propulsion Design Office, Office of Assistant Chief for Research, Development, Test, and Evaluation, Bureau of Naval Weapons, Department of the Navy, Washington, D.C.
 Lt. Col. John H. Anderson, U.S. Air Force, chief of Applications Division, Assistant Deputy Commander/Weapon Systems, Nuclear Programs, Air Research and Development Command, Andrews Air Force Base, Washington, D.C.
 Col. J. L. Armstrong, deputy assistant director (aircraft reactors), Division of Reactor Development, Atomic Energy Commission, Washington, D.C.

NASA staff representatives

Leroy V. Humble, Lewis Research Center.
 R. V. Meghreblian, Jet Propulsion Laboratory.
 David Novik, Headquarters, Secretary.

RESEARCH ADVISORY COMMITTEE ON MECHANICAL POWERPLANT SYSTEMS

Gordon Banerian, chairman, vice president, engineering, Aero jet-General-Nucleonics, San Ramon, Calif.
 D. Cochran, general manager, Flight Propulsion Laboratory Department, General Electric Co., Cincinnati, Ohio
 Merrell R. Fenske, director, Petroleum Refining Laboratory, College of Chemistry and Physics, The Pennsylvania State University, University Park, Pa.
 John R. Foley, technical and research project engineer, Pratt & Whitney Aircraft United Aircraft Corp., East Hartford, Conn.
 Cecil G. Martin, assistant manager, Engineering Department, Staff Research and Development Thompson Products Divisions, Thompson Ramo Wooldridge Inc., Cleveland, Ohio
 John L. Mason, chief of preliminary design AiResearch Manufacturing Co., The Garrett Corp., Los Angeles, Calif.
 Clyde McKinley, director, research and development, Air Products, Inc., Allentown, Pa.
 T. F. Nagey, Director of Research, Allison Division, General Motors Corp., Indianapolis, Ind.
 George P. Townsend, Jr., chief design engineer, Sundstrand Aviation, Rockford, Ill.
 Paul R. Vogt, chief engineer, liquid propellant engines, Rocketdyne Division, North American Aviation, Inc., Canoga Park, Calif.
 George F. Wislicenus, director Garfield Thomas Water Tunnel, c/o Ordnance Research Laboratory, The Pennsylvania State University, University Park, Pa.
 Hans G. Paul, chief, Propulsion and Mechanics Branch, Army Ballistic Missile Agency, Redstone Arsenal, Ala.
 Robert W. Pinnes, Systems Analysis Division, Office of Assistant Chief for Research, Development, Test, and Evaluation, Bureau of Naval Weapons, Department of the Navy, Washington, D.C.
 Ernest C. Simpson, chief, Turbojet and Ramjet Engine Branch, Propulsion Laboratory, Wright Air Development Division, Wright-Patterson Air Force Base, Ohio

NASA staff representatives

Bruce T. Lundin, Lewis Research Center.
 D. R. Bartz, Jet Propulsion Laboratory.
 Herbert D. Rothen, Headquarters, Secretary.

RESEARCH ADVISORY COMMITTEE ON ELECTRICAL POWERPLANT SYSTEMS

Krafft A. Ehricke, Chairman; program director, Convair-Astronautics, division of General Dynamics Corp., San Diego, Calif.
 Robert H. Boden, program engineer, Rocketdyne Division, North American Aviation, Inc., Canoga Park, Calif.
 W. H. Bostick, George Meade Bond professor of physics, Stevens Institute of Technology, Hoboken, N.J.

- Milton U. Clauser, vice president and director, Physical Research Laboratory, Space Technology Laboratories, Inc., Los Angeles, Calif.
 A. John Gale, vice president and director, applied physics, High Voltage Engineering Corp., Burlington, Mass.
 Siefried Hansen, technical director, Space Research Laboratories, Litton Industries, Inc., Beverly Hills, Calif.
 John H. Huth, Aeronautics Department, RAND Corp., Santa Monica, Calif.
 John S. Luce, Oak Ridge National Laboratory, Union Carbide Nuclear Co., Oak Ridge, Tenn.
 Paul Kappaport, physicist, research physics, RCA Laboratories, Inc., Radio Corp. of America, Princeton, N.J.
 William Shockley, Shockley Transistor Corp., Mountain View, Calif.
 V. C. Wilson, Physical Electronics Section, Research Laboratory, General Electric Co., Schenectady, N.Y.
 Ernst Stuhlinger, Director of Research Projects, Army Ballistic Missile Agency, Redstone Arsenal, Ala.
 Wayne C. Hall, Associate Director of Research for Nucleonics, Naval Research Laboratory, Washington, D.C.
 Hans J. P. von Ohain, Aeronautical Research Laboratory, Wright Air Development Division, Wright-Patterson Air Force Base, Ohio.

NASA staff representatives

- Joseph M. Hallissy, Jr., Langley Research Center.
 John C. Evvard, Lewis Research Center.
 R. C. Hamilton, Jet Propulsion Laboratory.
 James Lazar, Headquarters, Secretary.

RESEARCH ADVISORY COMMITTEE ON STRUCTURAL LOADS

- E. Z. Gray, Chairman; systems engineering director, Boeing Airplane Co., Seattle, Wash.
 Raymond L. Bisplinghoff, professor of aeronautical engineering, Department of Aeronautics and Astronautics, Massachusetts Institute of Technology, Cambridge, Mass.
 William M. Duke, vice president-director of research, Space Technology Laboratories, Inc., Los Angeles, Calif.
 H. J. Hoge, section head, Structures, North American Aviation, Inc., International Airport, Los Angeles, Calif.
 Albert J. Kullas, manager, Flight Vehicle Design Department, Martin Co., Baltimore, Md.
 George D. Ray, chief engineer, Aircraft Division, Bell Aircraft Corp., Buffalo, N.Y.
 Alfred I. Sibila, manager of space science, Vought-Astronautics, division of Chance Vought Aircraft, Inc., Dallas, Tex.
 Howard W. Smith, assistant chief of technical staff, Transport Division, Boeing Airplane Co., Renton, Wash.
 W. A. Stauffer Basic Loads Department manager, Lockheed Aircraft Corp., Burbank, Calif.
 Melvin Stone, chief of Strength and Dynamic Stability Section, Long Beach Division, Douglas Aircraft Co., Inc., Long Beach, Calif.
 Leo Stoolman, manager, Aerodynamics Department, Systems Development Laboratories, Hughes Aircraft Co., Culver City, Calif.
 Emil A. Hellebrand, Chief, Structures Branch, Army Ballistic Missile Agency, Redstone Arsenal, Ala.
 Clinton T. Newby, Airframe Design Division, Office of Assistant Chief for Research, Development, Test, and Evaluation, Bureau of Naval Weapons, Department of the Navy, Washington, D.C.
 Carl E. Reichert, Structures Branch, Aircraft Laboratory, Wright Air Development Division, Wright-Patterson Air Force Base, Ohio.
 Robert Rosenbaum, Supervisor, Dynamic Loads, Aircraft Engineering Division, Federal Aviation Agency, Washington, D.C.
 Philip Donely, Langley Research Center.

NASA staff representatives

- John F. Parsons, Ames Research Center.
 Thomas V. Cooney, Flight Research Center.
 Herman Bank, Jet Propulsion Laboratory.
 R. Fabian Goranson, Headquarters, Secretary.

RESEARCH ADVISORY COMMITTEE ON STRUCTURAL DESIGN

- E. E. Sechler, Chairman; professor of aeronautics, California Institute of Technology Pasadena, Calif.
 Lewis H. Abraham, chief, Strength Section, Missiles and Space Systems, Douglas Aircraft Co., Inc., Santa Monica, Calif.
 Norris F. Dow, specialist, structural systems, Missile and Space Vehicle Department, General Electric Co., Philadelphia, Pa.
 Mr. Lester K. Fero project manager, Advanced Design Division, Martin Co., Baltimore, Md.
 Mr. Christian M. Frey United Research Corp., Menlo Park, Calif.
 Mr. David Lee Grimes, president, Narmco Industries, Inc., San Diego, Calif.
 Dr. Nicholas J. Hoff, head, Division of Aeronautical Engineering, Stanford University, Stanford, Calif.
 Mr. William R. Micks, head, Structures and Materials, Aeronautics Department, RAND Corp., Santa Monica, Calif.
 John C. Moise, head, Preliminary Design Department, Liquid Rocket Plant, Aerojet-General Corp., Sacramento, Calif.
 Paul E. Sandorff, associate professor of aeronautics and astronautics, Massachusetts Institute of Technology, Cambridge, Mass.
 Robert S. Shorey, structures group, engineering, Convair-Astronautics, division of General Dynamics Corp., San Diego, Calif.
 E. H. Spaulding, chief technical engineer, California Division, Lockheed Aircraft Corp., Burbank, Calif.
 Erich E. Goerner, special assistant to Chief, Structures Branch, Army Ballistic Missile Agency, Redstone Arsenal, Ala.
 Ralph L. Creel, Airframe Design Division, Office of Assistant Chief for Research, Development, Test, and Evaluation, Bureau of Naval Weapons, Department of the Navy, Washington, D.C.
 William B. Miller, Structures Branch, Aircraft Laboratory, Wright Air Development Division, Wright-Patterson Air Force Base, Ohio.

NASA staff representatives

- Richard R. Heldenfels, Langley Research Center.
 Glen Goodwin, Ames Research Center.
 Jack B. Esgar, Lewis Research Center.
 J. D. Burke, Jet Propulsion Laboratory.
 Melvin G. Rosche, Headquarters, Secretary.

RESEARCH ADVISORY COMMITTEE ON STRUCTURAL DYNAMICS

- Martin Goland, Chairman; director, Southwest Research Institute, San Antonio, Tex.
 Holt Ashley, associate professor, aeronautics and astronautics, Massachusetts Institute of Technology, Cambridge, Mass.
 Michael Dublin, chief of dynamics, Convair, division of General Dynamics Corp., San Diego, Calif.
 Walter Gerstenberger, chief of dynamics, Sikorsky Aircraft Division, United Aircraft Corp., Stratford, Conn.
 Warren T. Hunter, chief, Guidance and Control Section, Missile and Space Systems Engineering Department, Douglas Aircraft Co., Inc., Santa Monica, Calif.
 H. Clay Johnson, configuration manager, Martin Co., Orlando, Fla.
 Robert G. Loewy, chief technical engineer, Vertol Aircraft Corp., Morton, Pa.
 John W. Miles, professor of engineering, University of California, Los Angeles, Calif.
 Raymond D. Mindlin, professor of civil engineering, Columbia University, New York, N.Y.
 John E. Stevens, assistant chief of structures, Chance Vought Aircraft, Inc., Dallas, Tex.
 M. J. Turner, dynamics staff engineer, Boeing Airplane Co., Seattle, Wash.
 Helmut F. Bauer, Chief, Vibration and Flutter Section, Aeroballistics Laboratory, Army Ballistic Missile Agency, Redstone Arsenal, Ala.
 Douglas Michel, Airframe Design Division, Office of Assistant Chief for Research, Development, Test, and Evaluation, Bureau of Naval Weapons, Department of the Navy, Washington, D.C.

M. J. Mykytow, Assistant Chief, Dynamics Branch, Aircraft Laboratory, Wright Air Development Division, Wright-Patterson Air Force Base, Ohio.

NASA staff representatives

I. E. Garrick, Langley Research Center.
 Albert Erickson, Ames Research Center.
 John C. Sanders, Lewis Research Center.
 Marshall E. Alper, Jet Propulsion Laboratory.
 Harvey H. Brown, Headquarters, Secretary.

RESEARCH ADVISORY COMMITTEE ON MATERIALS

R. H. Thielemann, Chairman; chairman, Department of Metallurgy, Stanford Research Institute, Menlo Park, Calif.
 Richard D. Baker, CMB Division leader, Los Alamos Scientific Laboratories, Los Alamos, N. Mex.
 L. L. Gilbert, head, Materials Department, Azusa Operations, Aerojet-General Corp., Azusa, Calif.
 Nicholas J. Grant, professor of metallurgy, Massachusetts Institute of Technology, Cambridge, Mass.
 L. R. Jackson, Coordination Director, Battelle Memorial Institute, Columbus, Ohio.
 Louis P. Jahnke, manager, metallurgical engineer Flight Propulsion Laboratory Department, General Electric Co., Cincinnati, Ohio.
 J. C. McDonald, Missiles and Space Division, Lockheed Aircraft Corp., Sunnyvale, Calif.
 E. Scala, chief, Materials Section, Research and Advanced Development Division, Avco Manufacturing Corp., Wilmington, Mass.
 E. N. Skinner, manager, Application Engineering, International Nickel Co., New York, N.Y.
 Wolfgang H. Steurer, chief of engineering materials, Convair, Division of General Dynamics Corp., San Diego, Calif.
 Hans Thurnauer, head, Ceramics Section, Central Research Department, Minnesota Mining & Manufacturing Co., St. Paul, Minn.
 E. J. Zeilberger, supervisor, materials engineering, Rocketdyne Division, North American Aviation, Inc., Canoga Park, Calif.
 Clarence Zener, director, Research Laboratories, Westinghouse Electric Corp., Pittsburgh, Pa.
 James L. Martin, Director, Ordnance Materials Research Office, Watertown Arsenal, Watertown, Mass.
 Nathan E. Promisel, Director, Materials Division, Office of Assistant Chief for Research, Development, Test, and Evaluation, Bureau of Naval Weapons, Department of the Navy, Washington, D.C.
 Col. J. V. Hearn, Jr., U.S. Air Force, Chief, Research Division, Directorate of Research and Development, U.S. Air Force, Washington, D.C.

NASA staff representatives

Paul Kuhn, Langley Research Center.
 Robert M. Crane, Ames Research Center.
 S. S. Manson, Lewis Research Center.
 L.D. Jaffe, Jet Propulsion Laboratory.
 Richard H. Raring, Headquarters, Secretary.

RESEARCH ADVISORY COMMITTEE ON AIRCRAFT OPERATING PROBLEMS

William Littlewood, chairman, vice president-equipment research, American Airlines, Inc., Washington, D.C.
 John G. Borger, chief project engineer, Pan American World Airways System, Long Island City, N.Y.
 Carl M. Christenson, assistant vice president, flight operations, United Air Lines, Inc., Denver, Colo.
 Warren T. Dickinson, assistant chief engineer, administration, Santa Monica division, Douglas Aircraft Co., Inc., Santa Monica, Calif.
 Jerome Lederer, managing director, Flight Safety Foundation, New York, N.Y.
 Perry W. Pratt, vice president and chief scientist, United Aircraft Corp., East Hartford, Conn.
 Clarence N. Sayen, president, Air Line Pilots Association, Chicago, Ill.
 George S. Schairer, vice president, research and development, Boeing Airplane Co., Seattle, Wash.

Arnold M. Small, manager, Reliability and Quality Assurance Laboratory, Engineering Laboratories, Hughes Aircraft Co., Fullerton, Calif.
 R. L. Thoren, chief flight test engineer, California Division, Lockheed Aircraft Corp.
 Capt. John Sinkankas, USN, Director, Airborne Equipment Division, Office of Assistant Chief for Research, Development, Test, and Evaluation, Bureau of Naval Weapons, Department of the Navy, Washington, D.C.
 Robert D. Fletcher, director, scientific services, Air Weather Service, Scott Air Force Base, Ill.
 Hon. James T. Pyle, deputy administrator, Federal Aviation Agency, Washington, D.C.
 Harry Wexler, director of meteorological research, U.S. Weather Bureau, Washington, D.C.

NASA staff representatives

H. A. Soule, Langley Research Center.
 L. A. Clousing, Ames Research Center.
 I. Irving Pinkel, Lewis Research Center.
 Joseph A. Walker, Flight Research Center.
 George P. Bates, Headquarters, Secretary.

APPENDIX K

REPORT OF THE NASA BIOSCIENCE ADVISORY COMMITTEE

(January 25, 1960)

MEMBERSHIP OF THE BIOSCIENCE ADVISORY COMMITTEE

(October 1, 1959, through January 25, 1960)^{*}

Seymour S. Kety, Director of Clinical Science Laboratory, National Institutes of Health, Bethesda, Md., Chairman.
 Clark T. Randt, Director of Life Science Programs, NASA headquarters, Washington, D.C., executive secretary.
 Wallace O. Fenn, professor of physiology, University of Rochester, Rochester, N.Y.
 David R. Goddard, director of the division of biology, University of Pennsylvania, Philadelphia, Pa.
 Donald G. Marquis, professor of psychology, Massachusetts Institute of Technology, Cambridge, Mass.
 Robert S. Morison, director of natural and medical sciences, Rockefeller Foundation, New York, N.Y.
 Cornelius A. Tobias, professor of medical physics, University of California, Berkeley, Calif.

CONTENTS

	Page
Summary and recommendations.....	155
I. The role of life sciences in the national space effort.....	155
II. A. Present status of life sciences activities.....	157
B. Advisory committees for space-oriented life sciences.....	158
III. Present needs.....	159
IV. Recommendations for a NASA program in the life sciences:	
A. Organization of the Office of Life Sciences.....	161
B. Intramural program of the NASA Office of Life Sciences.....	162
C. Extramural program of the NASA Office of Life Sciences.....	165
D. Relationship of the NASA Office of Life Sciences to existing programs in the military services.....	165
E. Training.....	168
F. Communication and information.....	168
G. NASA life sciences facilities as a public trust.....	169

^{*} This ad hoc committee dissolved after submitting its report to the NASA Administrator.

SUMMARY AND RECOMMENDATIONS

The role of the life sciences in the National Aeronautics and Space Administration program was evaluated by the Bioscience Advisory Committee at the request of the Administrator.

The objectives of space research in the life sciences are twofold: (1) Investigation of the effects of extraterrestrial environments on living organisms including the search for extraterrestrial life; (2) scientific and technologic advances related to manned space flight and exploration.

The same reasons which prompted the establishment of NASA and gave it responsibility for all space research and development devoted to peaceful purposes require that NASA assume responsibility for leadership, coordination, and operation of the biomedical aspects of the national space program.

Present and future needs were considered in three broad categories:

1. Basic biologic effects of extraterrestrial environments, with particular emphasis on those phenomena associated with weightlessness, ionizing radiation, and alterations in life rhythms or periodicity as well as the identification of complex organic or other molecules in planetary atmospheres and surfaces which might be precursors or evidence of extraterrestrial life.

2. Applied or technologic aspects of medicine and biology as they relate to manned space flight including the effects of weightlessness on human performance, radiation hazards, tolerance of force stresses, and maintenance of life-sustaining artificial environments.

3. Medical and behavioral scientific problems concerned with more fundamental investigation of metabolism, nutrition, blood circulation, respiration, and the nervous system control of bodily functions and performance in space equivalent situations.

The Bioscience Advisory Committee makes the following recommendations:

1. That NASA establish an Office of Life Sciences having the responsibility and authority for planning, organizing and operating a life sciences program including intramural and extramural research, development, and training.

2. That a Director of Life Sciences be appointed who is directly responsible to the Administrator of NASA in the same manner and at the same directional level as the other program directors.

3. That the internal organization of the Office of Life Sciences include Assistant Directors for basic biology, applied medicine and biology, medical and behavioral sciences, and the life sciences extramural program.

4. That an intramural life sciences program and facility be established with three sections:

- (a) Basic biology.

- (b) Applied medicine and biology.

- (c) Medical and behavioral sciences.

5. That the Director of Life Sciences recommend advisory committees made up of consultants outside of NASA to be appointed by the Administrator.

6. That maximum integration of the personnel and facilities applicable to the space-oriented life sciences in the military services and other Government agencies be arranged in the most appropriate manner indicated by the nature and extent of the specific problem at hand.

7. That the Office of Life Sciences assume proper responsibility for education and training in the space-oriented life sciences through postgraduate fellowships, training grants to institutions, and short-term visiting scientist appointments to be integrated with other NASA efforts in this area.

8. That the NASA life sciences program place special emphasis on the free exchange of scientific findings, information, and criticism among all scientists.

9. That security regulations be exercised with great caution and limited to matters in which national security is clearly involved.

10. That the NASA life sciences facilities be considered a public trust in implementing national and international cooperative efforts.

I. THE ROLE OF THE LIFE SCIENCES IN THE NATIONAL SPACE EFFORT

The Congress of the United States has given to the National Aeronautics and Space Administration the responsibility for all space research and development devoted to peaceful purposes. NASA has begun the fulfillment of this responsibility with an emphasis on the physical and engineering sciences which occupy a fundamental position by virtue of their pertinence to the design, launching, and control of all vehicles, whatever their ultimate scientific purpose. With this aspect of the total program well under way, attention is properly being directed to other

disciplines which, though dependent on the engineering sciences, will in turn give scientific meaning to the national effort. The biological, medical, and behavioral sciences are among these disciplines. The Bioscience Advisory Committee has been appointed to aid in representing them adequately within the NASA program.

The reasons which prompted the Congress to create NASA as a civilian space agency and to give it responsibility for achieving the peaceful purpose of the national effort in space argue equally strongly for the creation in NASA of a strong division of life sciences. As set forth below, two major areas represent the role of the biological sciences in the national space effort and should form the core of the proposed program in the life sciences of NASA. These are the fundamental biological questions relative to extraterrestrial environments and the scientific and technologic aspects of manned space flight.

It is altogether fitting that these matters, both of which involve man's curiosity about himself and his environment in their broadest and most fundamental sense, should be placed in the hands of an agency broadly representative of society as a whole. The military agencies which have so soundly laid the groundwork for much of existing space technology must properly give primary attention to the development of weapons systems and the national defense. Although the military effort in astronautics should not be arbitrarily restricted by narrow definitions of military relevance, the broader implications of extraterrestrial exploration demand the attention of an organization unhampered by such predetermined objectives.

Space exploration has captured the imagination of men the world over to an extent which was not, perhaps, anticipated. These activities have become representative of technological superiority among nations. The United States must maintain its international role as a strong and self-confident but basically peaceful and benevolent power. This requires that the first of her citizens who enter space do so as representatives of the scientific aspirations of all men and not as a symbol of military strength.

The basic study of extraterrestrial environments is ultimately likely to be most productive in furthering an understanding of the fundamental laws of nature. Among the most perplexing questions which have challenged men's minds are the nature and origin of life and the possibility of its presence elsewhere in the universe than on the Earth alone. For the first time in history, partial answers to these questions are within reach. Limited knowledge acquired over the past century concerning atmospheric and climatic conditions on other planets, the topographical and seasonal variety in color of the surface of Mars, the spectroscopic similarities between scattered sunlight from portions of that planet and those demonstrable from algae and lichens on Earth have suggested the presence of extraterrestrial environments suitable for life and permitted the formulation of hypotheses for the existence there of some forms of life at present or in the past. These hypotheses may, within the foreseeable future, be tested, at first indirectly by astronomical observations made beyond the interference of the Earth's atmosphere and by samplings taken mechanically from various celestial bodies, and finally, by direct human exploration. The discovery of extraterrestrial life and a description of its various forms, knowledge of the presence and types of complex molecules based on carbon or other elements, or conversely, the absence of living organisms or of their traces in environments conducive to life will have important implications toward an ultimate understanding of biological phenomena.

These studies will not be complete until the scientist himself is able to make meticulous investigations on the spot. This is true, not only for the biological but, also, for many other physical, chemical, and geological problems which are involved. Although significant engineering achievements in automation, sensing, recording, programming, and telemetering have been realized and considerable future development is in prospect, the indispensability of the human observer in much of space exploration is well established. Man's versatility and selectivity, his ability to perceive the significance of unexpected and unprogrammed findings or to react intelligently to unanticipated situations have not been simulated by any combination of physical devices, however, complex, which have been developed or are even contemplated. Human intelligence and manual skill in servicing the complicated mechanisms of space vehicles or repairing breakdowns in flight are not readily dispensed with or replaced. When along with these attributes are considered his weight of 70 kilograms, his total resting power requirements of 100 watts, his ability to function for years without maintenance or breakdown, then even the most elaborate provisions for his sustenance, welfare, and safety are amply justified simply in terms of engineering efficiency. A national program in space science which does not recognize the

essentiality of the human observer and does not plan to utilize him most effectively may wait indefinitely for the automatic devices to replace him or be limited to incomplete and opportunistic observations.

Putting a man into space, especially if he is to stay for long periods, is a task which involves considerable attention and effort from a wide variety of biological, psychological, and medical specialties. It will require careful planning and extensive basic and developmental research. Together with the effort in astrobiology it should constitute a substantial part of the total space research and development enterprise.

It comes as no surprise to find that the early stages of space research have been primarily concerned with engineering matters. To many responsible people it seems premature if not actually presumptuous to think about what man will do in space until we are sure that we can actually put him there. But the validity of even the earliest of engineering decisions must be continually appraised in terms of their capacity to maintain man comfortably and effectively in space and increase his knowledge of its properties. Failure to meet numerous and often subtle physiological and psychological needs of the human organism, or premature decisions to send man off into an unknown universe can have disastrous effects not only on the individuals concerned, but on the Nation's political and moral position in the eyes of the world. The scientific objectives of the program and especially the determination of the nature of extraterrestrial life may be forever rendered impossible if vehicles containing complex organic molecules are carelessly allowed to contaminate celestial bodies before science has had a chance to study the original conditions. Nor can we simply ignore the perhaps remote possibility that infective organisms brought back from space to earth may cause human disease or destroy food crops essential to human life. How is the necessary biological wisdom to be brought to bear in planning the space effort?

As pointed out later in this report, the Nation's best scientific brains are already organized in the form of advisory committee to study and consult on every detail of the space problem. However, such outside bodies, no matter how soundly constituted, cannot have effective impact on day-to-day decisions within the space agency unless the agency itself is provided with a sensitive and powerful administrative mechanism for receiving the advice and translating it into the energy of decision.

To implement this program in the life sciences, appropriate in size and importance to its responsibilities, it is essential to have in NASA a Director of Life Sciences reporting directly to the Administrator of NASA so that the biomedical interests and skills will have adequate representation in important decisions. The director of the life sciences program, therefore, must have broad biological training and interests. He must be able to understand the physicists and engineers as well as have the ability to present biomedical aspects of combined problem areas effectively to his colleagues so that he can have appropriate influence on comprehensive policies and decisions.

These reasons compel the committee to emphasize that the NASA life sciences program requires and deserves strong financial support and adequate administrative representation.

II

A. Present status of life sciences activities

The present status of activities in the space-oriented life sciences may be considered under the general headings of basic biology; medical and behavioral sciences; and applied medicine and biology. Current activities are predominantly in the third category which includes research and development in manned space flight technology for five major programs:

(a) The NASA-Air Force-Navy X-15 rocket-powered research aircraft project begun in 1954 utilizes a "near space" vehicle expected to reach altitudes of about 100 miles. The first powered flight to approximately 60,000 feet has recently been accomplished.

(b) Project Mercury was organized by NASA in October 1958 to (1) place a manned space capsule in orbital flight around the Earth; (2) investigate man's reactions and capabilities in this environment; and (3) recover the capsule and pilot safely. The NASA Space Task Group responsible for Project Mercury includes military medical personnel and pilots on temporary duty with NASA at Langley Research Center.

(c) The Air Force Discoverer project is concerned with recoverable polar orbiting earth satellites, one of which contained mice, and later will include monkeys,

to test life support systems and the effects of space flight on animals as well as testing techniques for recovery of the capsule and occupants.

(d) Contracts have been let recently by the Air Force to implement the Dynasoar program for development of a manned maneuverable boost glide vehicle to explore hypersonic performance up to orbital speeds and to investigate the accompanying reentry problems.

(e) Supporting medical research and development in applied medicine and biology is being carried out in existing military aviation medical facilities. Among 40 service biomedical laboratories, 15 have noteworthy bioastronautics capabilities. The cost of these facilities is roughly estimated to be about \$80 million. The 1960 Department of Defense budget for life sciences research and development is \$47 million, including approximately \$10 million for bioastronautics. The NASA research centers are continuing studies utilizing fixed base flight simulators and variable stability aircraft to further delineate man's function in aircraft operating problems. Several dynamic flight simulators capable of reproducing some portions of space flight mission profiles are now being developed at the Langley and Ames Research Centers. Biomedical participation in these projects is, at present, insufficient. The larger aircraft companies are investing several million dollars in space flight technology this year. The latter effort is mainly concerned with bioengineering and technical development.

In addition to the considerable amount of work specifically designed to solve recognized biotechnical problems connected with space flight, there is an even larger amount of work which, although nominally carried on for other purposes, contributes to the field of space medical and behavioral science. One may cite, for example, those studies now being carried out in universities, medical schools, the National Institutes of Health, and under the auspices of the Atomic Energy Commission dealing with physical stress, including ionizing radiation, environmental physiology, and behavior.

In contrast to the large amount of work bearing on practical problems of space medicine, space-oriented basic biological research has received little attention to date. A relatively small group of university biochemists and biophysicists have recognized that space exploration offers a unique opportunity to study the origin of life and the effects of extraterrestrial environments on living organisms and they have tried to formulate some definite plans for appropriate research.

B. Advisory committees for space-oriented life sciences

Senior representatives of the Army, Navy, and Air Force recommended late in 1957 that the National Academy of Sciences provide, through the National Research Council, an advisory committee in the life sciences covering all biological and psychological fields of interest in the space environment. This led to the establishment of the Armed Forces-National Research Council Committee on Bioastronautics under the Division of Medical Sciences of the National Academy of Sciences. Dr. Otto Schmitt was appointed chairman. This group includes 180 individuals from civilian institutions, the military services, and Government agencies. The Committee on Bioastronautics is more comprehensively represented in the man-in-space problem areas, although there is considerable basic biological representation as well.

Dr. W. Randolph Lovelace II was appointed Chairman of the NASA Special Committee on the Life Sciences by Dr. Glennan in October 1958. Its role has been essentially that of an advisory panel for Project Mercury.

The Space Science Board of the National Academy of Sciences was established in 1958. Of the 12 committees of this Board, only one has particular relevance in the biological area, the Committee on Psychological and Biological Research. Dr. H. K. Hartline is chairman of this committee which has expressed general interest in the man-in-space program but has found its principal concern in basic biology, particularly the areas related to problems of extraterrestrial contamination and the detection of extraterrestrial life. To focus attention of biologists on these problems, Dr. Hartline's committee joined with the long-range planning committee of the Space Science Board to set up two additional groups designated EASTEX and WESTEX, chaired by Dr. Bruno Rossi and Dr. Joshua Lederberg, respectively. The names of these latter two committees derive from a committee (CETEX) established by the International Council of Scientific Unions to explore problems of extraterrestrial contamination.

The functions of this latter organization have now been absorbed by the Committee on Space Research (COSPAR) within the International Council of Scientific Unions.

Liaison between these planning and advisory groups has been established by appointing a number of individuals as members of two or more groups. The

effectiveness of these committees has been limited by the lack of an overall operational life sciences program which would implement the suggestions of the committees to make the best use of the unprecedented opportunities provided by space exploration.

III. PRESENT NEEDS

(a) *Basic biology*

In order to attain overall objectives in the space-oriented life sciences, an imaginative and long-range program in the broad field of astrobiology is required. This should include the further development of hypotheses relating to the origin of complex organic molecules and of living matter, further observation, both from the earth and from artificial satellites, of the surface environments of neighboring celestial bodies, studies on the adaptive effects of simulated extraterrestrial environments on various forms of life in successive generations, the study of meteorites and "cosmic dust," and, eventually, the exploration by man of lunar and planetary surfaces for complex molecules, organic substances, or evidence of forms of life. Indeed, one of the most important justifications for an extensive effort in space exploration is the promise which it offers of substantial advance in our understanding of these basic problems in biology and astrophysics. From this point of view the biomedical and engineering task of achieving human space travel is but a means to that end.

With this in mind, a program should be initiated shortly and projected indefinitely into the future in which a significant number of payloads would be dedicated primarily to biomedical purposes. These should be engineered from their inception with biological purposes in mind as opposed to the present opportunistic "space available-noninterference" provision. The payloads should be engineered to biological specifications. The trajectory should be carefully chosen for each experiment with regard to specific biological objectives. All worthy experimental investigations proposed by members of the scientific community should be given consideration for available biomedical payloads.

(b) *Applied medicine and biology*

The present program in this area appears to be centered on Project Mercury, the aim of which is to put a man safely into space for several orbital flights about the Earth before return and recovery. There is need that this worthwhile phase of space research and development be adequately supported but also that it be integrated with proper perspective into a long-range biomedical program with respect to its scientific objectives, its timing, and its budgeting. For reasons which have been outlined earlier in this report, the committee believes that human observers, properly trained in the appropriate scientific disciplines, are indispensable components of space research. Project Mercury, by marshaling a wealth of engineering and biomedical effort on one step toward that goal, is fulfilling an important and necessary first objective. This project also has certain values in terms of technical and scientific achievement and prestige on a national and international scale. It is even more important that the thought and effort which have been devoted to questions of human safety be continued and emphasized, that the peaceful scientific objectives be clearly delineated, augmented, and stressed, that attention be given to increasing the scientific information to be obtained from the project, and that these data be made widely available in order that this great effort be perceived as a sober scientific mission rather than a tour de force.

Problems relevant to manned space flight which require and are presently receiving attention are many in number. Several major groups are discussed below and a summary of the various problem areas in various disciplines which are relevant to space bioscience are given in Table I, p. 161.

1. *Weightlessness*.—The effect of weightlessness is an unusual one in that its simulation for prolonged periods can only be achieved in satellites or space ships. A number of consequences are possible. Certain physical properties of matter in the solid, liquid, and vapor states may be significantly affected. The method of heat convection and diffusion may be radically altered. It is possible that intracellular events could occur in different time sequence. Plants and other living forms, which normally grow against gravity, may take on peculiar morphological characteristics. Many physiological variables may undergo change; for example, neural and cardiac function, circulation, and metabolism. The sensory basis for normal bodily orientation will be profoundly altered. The effects of gravity-free states and various low-gravity conditions should be investigated in a variety of living forms in satellites on both short and long flights.

2. *Force stresses*.—In space flight many mechanical factors and forces occur that are encountered only in small measure at ground level. Great forces pin

down the astronaut during initial acceleration and reentry as well as during emergency escape. Spinning, tumbling, vibration, and noise present environmental stresses which require further study. The Armed Forces laboratories have made significant advances in studies of the physiological effects of such forces, but further information could be provided by new centrifuges and other simulators with more degrees of freedom of motion and combinations of stresses.

3. *Radiation*.—Radiation in space presents a great challenge to physical as well as biological scientists. There are intense and not fully explored radiation belts in the magnetic field surrounding the earth. In addition, many particles arrive on the surface of the earth from space and from the sun. Some of these have not as yet been fully explored and only part of the radiation spectrum has been reported at ground level in accelerators to date. Among the cosmic radiations, there are large streams of the nuclei of light and heavy atoms which can produce untoward biological effects. Their study, utilizing the tools of radiobiology, will provide more information about living processes. Such studies should include additional physical measurements and biological assay of the radiations in space, their simulation at ground level, and finally direct experiments on living material of all types in satellites to provide quantitative empirical information on various biological effects not only on immediate metabolism and function but also on survival, longevity, carcinogenesis, and mutations.

4. *Closed environment*.—If man is to explore space, he will need to live in the closed and isolated environments of the space vehicles and stations. Even after the first landings on planets, he will probably have to be constantly maintained in an artificial environment compatible with functional effectiveness as well as survival. Storage and supply of oxygen, water, and nutrients and the disposal of carbon dioxide and wastes are problems to which a number of partially satisfactory solutions have already been obtained. For long-term missions, biological or chemical systems for regenerating the essential requirements of human metabolism from its products are presently in the early stages of development. Certain psychological concomitants of confinement, isolation, and diminution of sensory input are of far-reaching consequences and their investigation is relatively new.

Because many of these problems are also encountered in present military operations most of the recent and current progress in these areas has come from the armed services.

5. *Changes in ambient time cycles*.—On earth, living organisms are geared to a 24-hour cycle. It is possible to detect diurnal periodicity in most biological variables. Spaceships or planetary stations will provide entirely different periods to which the organism will adjust with varying degrees of success. The problems of physiological and psychological adaptation are broad ones which can be studied in terrestrial as well as extraterrestrial laboratories.

6. *Toxicity and contamination*.—Biologists and medical scientists are interested in contamination carried by us into space, in the form of viruses and micro-organisms, as radioactive matter when reactor or nuclear explosions occur, or in the form of chemical compounds which might profoundly modify our own atmosphere to the extent that they become health hazards. The polonium battery and fluorine-containing rocket fuels are examples of gravely toxic materials. NASA should maintain a competent staff to deal with such health hazards, and future engineering planning should be subject to critical review and necessary limitations for public health protection.

In closed space vehicles, atmospheric contaminants ordinarily of negligible importance may achieve toxic concentrations and require special attention.

(c) *Basic medical and behavioral sciences*

Solutions to immediate, practical problems such as those exemplified above depend upon a broad base of information obtained in more fundamental aspects of medicine and behavioral sciences. Although much of that information is being accumulated in the course of the extensive research in these fields in universities and medical institutions, the needs of space science are especially dependent upon a number of specific areas, examples of which may be outlined as follows:

1. *Respiratory physiology*—including the control, mechanics and physical chemistry of mammalian respiration; gaseous diffusion and exchange; effects of alterations in ambient conditions of pressure and temperature.

2. *Circulatory physiology*—including circulatory reflexes, the control of the circulation, its response to gravitational and accelerative stress, to alterations in oxygen and carbon dioxide tensions and temperature change.

3. *Metabolism*—including energetics, nutrition, hibernation, digestion, excretion.

4. Neurophysiology—including postural and righting reflexes, physiology of vision, audition, proprioception, and orientation; central control of metabolism, temperature, endocrines, circulation, and respiration; circulation and metabolism of brain.

5. Behavioral science—including perception, motivation, and performance under stress, emotional stability, fatigue, social and sensory isolation, psychological assessment, and training for special missions.

TABLE I.—*Problem areas in the life sciences*

Extraterrestrial life	Stress factors	Radiation	Closed environments
Interplanetary matter. Planetary atmospheres. Molecular composition on planets. Unknown forms of life. Extinct life. Primordial life. Planetary systems in the universe. Terrestrial life on different planetary environments. Biological cross contamination. Chemical contamination.	Compression-decompression. Acceleration. Weightlessness. Spin and tumbling. Vibration-shock. Noise. Dust particles and meteorites. Isolation, confinement, and fatigue. Optimum mechanical integration of systems in manned satellite stations. Methods of escape and communication.	Microwaves. Infrared. Visible. Ultraviolet. X-rays. Van Allen Belt. Cosmic rays. Nuclear power and propulsion devices.	Photosynthesis. Chemical oxygen-carbon dioxide exchange. Control of closed atmospheres. Nutrition. Temperature-pressure. Clothing. Water balance. Waste products. Toxicity. Microbial flora. Theoretical stability. Energy balance. Hibernation—suspended animation. Psychological and physical support for well-being. Communication. Monitoring, warning, and safety devices.

IV. RECOMMENDATIONS FOR A NASA PROGRAM IN THE LIFE SCIENCES

A. Organization of the Office of Life Sciences

This Office should have the responsibility and authority for planning, organizing, and operating the life sciences program of NASA, including intramural and extramural research, development, and training. This Office would also advise and consult with the other divisions of NASA and with the Administrator in matters involving biology, medicine, and psychology. It should have the responsibility for safeguarding the welfare of human subjects and the public health as well as definitive participation in those projects which might jeopardize satisfactory investigation of possible extraterrestrial life.

1. The Director of Life Sciences would be vested with the responsibility and authority of the Office of Life Sciences and should be responsible directly to the Administrator of NASA in the same manner and at the same directional level as the other program directors. The calibre of the incumbent is obviously of fundamental importance. He should be a man of high scientific stature, an able administrator with demonstrated capability in the selection and direction of staff. It is probable that the Director will be found among physicians who have had considerable experience in the basic medical sciences, although there are others who are not physicians who might have the requisite background.

2. *The internal organization of the Office of Life Sciences.*—The Committee proposes that the Office be organized in four sections, each with an Assistant Director responsible to the Director of Life Sciences.

- (a) Section on Basic Biology.
- (b) Section on Medical and Behavioral Sciences.
- (c) Section on Applied Medicine and Biology.

The substantive nature of the program of each of these three sections is indicated under the respective heading in section III of this report, although considerable latitude in planning should be given to each Assistant Director.

- (d) Section on Extramural Program.

This section should be responsible for the administration and in collaboration with the other assistant directors, and the Director of Life Sciences, the planning of the extramural program.

3. *Advisory committees.*—The Director of Life Sciences may desire an advisory committee made up of consultants outside the NASA, recommended by him and appointed by the Administrator. Such a committee would normally report to the Director of Life Sciences or on occasion directly to the Administrator of the NASA.

The assistant directors of the four sections may well need advisory committees for their activities. These could be made up of NASA personnel plus outside consultants.

B. Intramural program of the NASA Office of Life Sciences

For a number of cogent reasons, an intramural program in the life sciences of significant size, diversity, and excellence should be established by the NASA. It is urgent that this program be initiated without delay.

1. *Objectives.*—The present research effort in this field within NASA appears to be concentrated upon a single specific goal, exemplified by Project Mercury, at the possible expense of broader, more remote, but fundamental aims. It is important that the biomedical aspects of the Project Mercury be placed squarely under the jurisdiction of the Office of Life Sciences and that it be coordinated with other aspects of the life sciences program. The remainder of the national space biomedical effort, as found in military, industrial and academic laboratories, is sporadic and incidental to other primary interests or responsibilities. These efforts are, on the whole, of excellent quality and should be maintained and supported; there is need, however, in addition to these and coordinated with them, for a broad and thoughtfully planned biomedical program of research extending from the most fundamental aspects to their most practical applications. The nucleus of such a national undertaking should be the NASA intramural program in biology, medicine, and psychology.

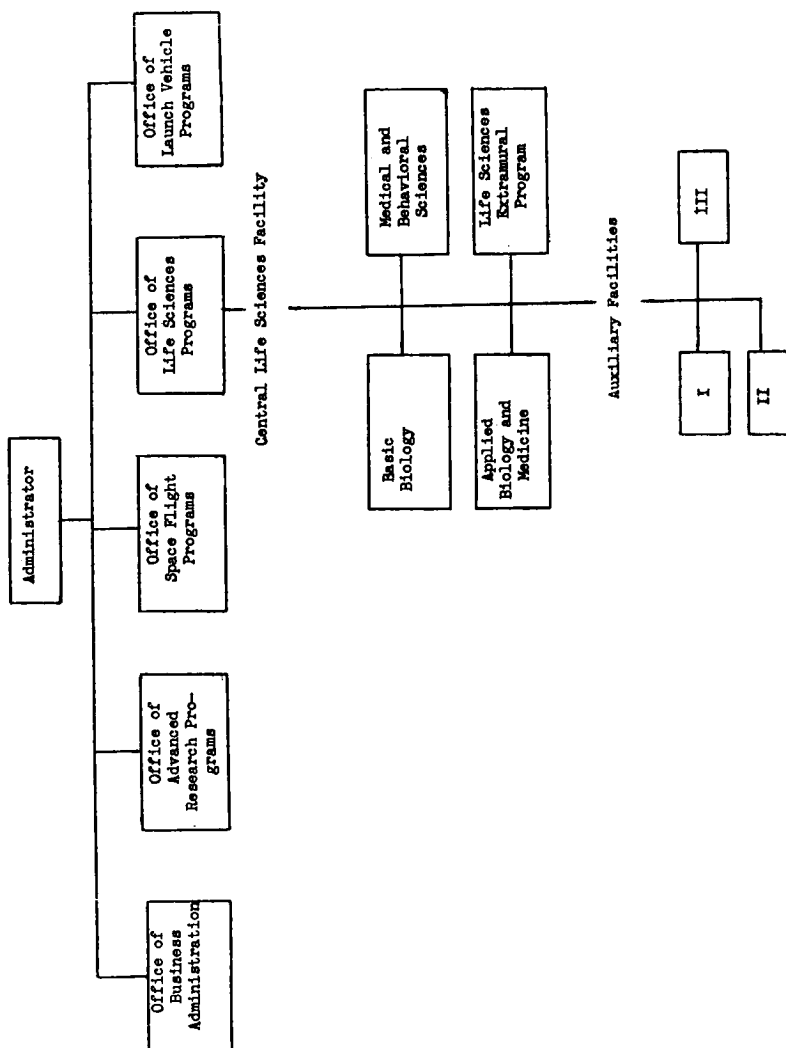
The number of competent biological, medical, and psychological scientists motivated toward space research and skilled in its special problems and techniques is, at present, seriously limited. It is necessary to create a number of career opportunities in these fields on a long-term, full-time basis and to increase the number of laboratories and facilities in which postgraduate training for such careers may be accomplished.

An important ingredient of a productive and creative research effort is the opportunity for interaction among scientists in all the relevant disciplines; between those whose interests are in the fundamental areas and those working in the applied aspects of the problem. The need for interaction has become essential in recent years as the result of the high degree of specialization which modern science and technology demands and the accelerating rate at which new knowledge is accumulating. The older formula for creativity which depended upon the accumulation by a single mind of all the information necessary to a new concept is becoming increasingly difficult to achieve; it may, partially at least, be replaced by the daily contact and collaboration among scientists within a single institute.

An active and distinguished research program in the biological, behavioral, and medical sciences within NASA should provide an atmosphere of knowledge and responsibility in which the national effort in these fields can best be planned, administered, and coordinated. It should be represented at the highest administrative levels within NASA and should participate in the planning and direction of the entire space program. Its members should be available for consultation and should be given appropriate responsibility and authority in all of NASA activities which involve biology, medicine, or psychology.

2. *Scope of intramural life sciences facilities.*—To fulfill these objectives the Committee recommends an intramural research program whose ultimate dimensions may be envisioned as follows:

(a) A broad central facility with laboratories ranging from the most basic biological, behavioral, and medical disciplines through their highly applied aspects. A site at Goddard Space Flight Center at Greenbelt, Md., or adjacent to the National Institutes of Health recommend themselves, each for somewhat different reasons. The latter would offer the advantages of the unsurpassed facilities of the National Library of Medicine and of interaction with basic and clinical medical, behavioral, and biological scientists at the National Institutes of Health, the adjacent Naval Medical Center, and the Walter Reed Army Medical Center, and Armed Forces Institute of Pathology which are only a few miles away. All of these opportunities would make the NIH site especially advantageous and attractive to scientists in the medical, biomedical, and behavioral fields. The Greenbelt site, on the other hand, would offer active interfaces both with the space sciences and space technologies and also with the basic biological sciences represented in the laboratories of the Department of Agriculture. This site has a further advantage in the potential for expansion as a national space center which the greater congestion and the different orientation of the NIH could not make possible. Further plans regarding the facility should be the responsibility of the Director of Life Sciences and his staff who will make specific recommendations to the Administrator.



(b) A limited number of additional facilities situated at some of the present or future NASA installations and possibly an institute at one or two universities. Each of these accessory groups would be somewhat differently oriented depending on the special functions and the variety of competences represented in their environs. Thus, an institute located at a university with an important biological tradition should be more heavily weighted toward basic astrobiology, while one situated where astronomy and physics were emphasized should reflect an orientation toward astrophysics. The groups to be incorporated into NASA installations, on the other hand, should be primarily representative of the technological and engineering aspects of biology and medicine. They would thus be in a position to utilize the unique facilities of these installations in the furtherance of astronomical research and, conversely, this would insure that engineering development of space vehicles would be carried out with due regard for the requirements of future occupants.

The Committee is reluctant to stipulate the dimensions which these facilities should attain or to indicate more precisely their scientific complexion. It would suggest, however, that the directors would give prior consideration to high quality rather than quantity, realizing that excellence is not necessarily proportionate to size.

It would emphasize, however, that at least some of the peripheral units, as well as each of the three units of the central facility, be planned in terms of a minimum critical mass, defined as an adequate variety of disciplines and number of professional personnel and their necessary supporting staff and physical facilities to constitute a self-sufficient, mutually interacting, and sustaining unit. It is of interest that the varied experience of the Committee members converged on an estimate of 20 scientists and 30 to 35 supporting personnel as constituting such a minimal staff. An annual budget of \$800,000, exclusive of permanent equipment but including overhead or reimbursement, would probably be required to support such a minimum unit, and a facility of 30,000 square feet, overall, to house it, based upon acceptable standards of biomedical research in other fields. This would indicate therefore an annual budget for the central facility of the order of \$2.4 million and a total of 90,000 square feet.

Even where the program of a unit were oriented to one or another aspect of the field as would be the case in the accessory laboratories, the scientific staff should be representative of numerous disciplines, basic as well as applied.

3. *Development of the intramural program.*—The rate of growth toward an intramural program of the scope outlined above will perforce be limited by the total budget and the competitive needs of the parent agency. More important, perhaps, may be the limitation, self-imposed by the program's directors in recognition of the paucity of adequately trained personnel and the other national needs for such individuals, including the needs by the military departments for national defense and security and the needs of academic and other institutions for teaching and research.

The committee recommends, therefore, that the development of the intramural program be deliberate and gradual with cooperative utilization of presently available manpower and facilities which are outside of NASA and their judicious duplication or replacement by the intramural NASA program as those facilities become obsolete or overutilized and as the total resource of competent and motivated scientists is augmented by a training program which NASA itself will substantially support.

The immediate and most pressing need of the program is the appointment of a Director of Life Sciences and, on his recommendation, the assistant directors. (See sec. IV-A. Organization.) It should be the responsibility of the Director and his assistant directors, in consultation with an advisory council, should one be appointed, to plan a national program for NASA in the life sciences, to determine its complexion, establish its philosophy, recruit its senior personnel, and guide its development.

The committee recommends that the Director of Life Sciences and his staff in their initial planning select those segments of the national program which are currently being carried out by existing facilities in the military services, in universities and research institutes, and by industry, or which certain of these facilities are capable of carrying out in the immediate future. By appropriate contracts, transfer of funds, construction grants or other mechanisms of support, participation of these existing facilities in a coordinated national program should be invited and made feasible.

At a very early date, the Director of Life Sciences and his staff should begin the planning, construction, and organization of the central and certain of the

auxiliary facilities, concentrating on those areas of basic and applied science not adequately provided for in existing programs.

As major physical facilities utilized by the NASA biomedical program on a cooperative basis and of primary concern to that program (i.e., centrifuge and controlled environmental chambers) become obsolete or overutilized, or as completely new designs become necessary and feasible, these may be constructed by NASA within its intramural program and maintained as national and international facilities. This should not prevent the construction of similar facilities by other agencies where necessary to the execution of their respective responsibilities. Present cooperative arrangements are a fitting precedent for the continuance of the concept that these expensive facilities should be shared wherever possible both in cost and usage, but that the initiative and responsibility for the construction of any one of them should lie with the agency which has the greatest need.

C. Extramural program of the NASA office of life sciences

Investigations in extraterrestrial biology and resolution of problems related to manned space flight provide an area for research and development necessitating many diversified contributions. An optimum rate of achievement will require further cooperation with other Government agencies. Important contributions are expected to come from scientists working in universities, research institutes, and industry. Thus a strong extramural program is an essential aspect of the activities of NASA in the life sciences: (1) to mobilize the relevant research talent; (2) to obtain ideas, information, and participation essential to the activities of NASA from the best qualified available sources; (3) to generate among the scientific and industrial communities an awareness of the activities of NASA and to secure support of its programs.

1. *Grants.*—NASA should set up a system of research grants for individual scientists or groups of scientists working in universities or nonprofit research institutes based on original research proposals and with appropriate means for their review and approval. Such grants should be for the support of basic or applied research in areas of interest to NASA. These areas of its interest should be broadly interpreted. Proposals from well-qualified interdisciplinary groups should be encouraged.

2. *Contracts.*—We believe that the NASA should enter into contracts with industrial corporations and governmental agencies for specific research needs, particularly in the field of technology but also in fundamental research. Such research contracts are particularly favorable for the solution of short-term problems which might be inefficiently studied in an intramural program and which might require the hiring of specialized scientists or the building of particular equipment that would have no long-term value to the agency,

3. *Timing.*—The committee strongly recommends that the grant program and perhaps research contracts should be initiated so that money is available to the recipients at the earliest practicable date. The initiation of this program need not await the setting up of the permanent organization of the life sciences. The NASA may be able to borrow an experienced official from the U.S. Public Health Service, the Office of Naval Research, or the National Science Foundation to get this program underway. Alternately, the NASA could delegate the approval of such grants to the National Research Council-National Academy of Sciences. The sort of study section mechanism used by the U.S. Public Health Service could serve as an excellent model.

D. Relationship of the NASA Office of Life Sciences to existing programs in the military services

The effort to put living animals and men into space and to maintain them there for considerable periods of time requires the development of many new techniques for protection from unfamiliar stresses. The nature of these stresses is reviewed elsewhere in this report. Study of the physical, chemical, biological, and psychological stresses of space flight requires an extensive array of apparatus and a large staff of trained scientists and technicians. Additional facilities and close liaison with the physical scientists and engineers engaged in vehicle research and development are essential to provide proper life support systems and protection for the passengers in this new form of transportation.

The existing capability for studies of this character is found almost entirely in the military services. Except for a few aircraft companies, civilian agencies have had little need to develop studies on high altitude, high-speed flight, and NASA itself has so far concentrated almost entirely on the physical and engineering aspects of flight problems.

The military medical services on the other hand have been continuously engaged since the First World War in developing facilities and personnel for aeromedical studies. No attempt will be made here to draw up a list of the facilities now available. It is only necessary to note that taken together, these installations provide a variety and quantity of controlled environment chambers, centrifuges, acceleration tracks, and other relevant apparatus which may not be equaled anywhere else in the world. The committee was especially impressed with the quality of the personnel available for work in these laboratories and their enthusiastic dedication to the job. It is difficult to measure the existing capability in terms of money but the investment in men and machines must represent at least \$80 million and perhaps a good deal more. More important is the time which would be required to build similar installations or train comparable personnel for use elsewhere.

It appears that the military capability in aeromedicine is, at present, not fully utilized. The reasons for this are somewhat complicated and require at least brief exposition. In the first place many of the biomedical problems of conventional high-altitude flight are now reasonably well solved. Furthermore, the military requirement for conventional aircraft is increasingly uncertain. Fewer such vehicles are planned for the future and there appears to be a declining need for the use of existing aeromedical facilities for the training and indoctrination of conventional pilots. Current military plans emphasize the use of unmanned ballistic missiles. Although certain forward-looking elements at various points in the Military Establishment foresee a tactical need for manned vehicles in space, such weapons systems do not form a major part of current operational plans. The military budgets for aeromedical research are not therefore defended at present on the basis of a clearly defined existing military objective or requirement. They depend for the most part on the declining momentum of the conventional aircraft program, and the existence of a few experimental projects of which the X-15 and Dyna-Soar vehicle series are examples. For completeness, it may be noted also, that understanding of aerospace medicine benefits indirectly by research funded for other reasons. For example, work on hot, noisy environments desired by the Tank Corps may help in understanding some of the biological problems involved in satellite launchings; closed ecological systems under development for use in submarines may be adapted to space vehicles; and so on.

Somewhat paradoxically, NASA, which does have a clearly defined mission to put and maintain men in space, has essentially no existing capability for studying the biological and medical problems involved. Faced with the necessity for selecting a group of astronauts for Project Mercury and providing for their safety during this series of missions, the agency turned for assistance to the military services. The services in turn, have responded with enthusiasm and goodwill to this new challenge. In spite of the apparent success of the arrangement, the fact remains that authority for insuring the health, safety, and effective functioning of the astronauts is not firmly in the hands of the agency responsible for the success of the project as a whole. The medical personnel were not selected by the NASA but by representatives of the military services which provided them on a loan basis for this particular task. Their continued presence in the project is as much a matter of continuing goodwill as it is a clear contractual agreement, and the individuals themselves must of necessity feel a primary loyalty to the services in which they have elected to develop their entire careers.

The establishment of an Office of Life Sciences in NASA will greatly improve its capability for discharging its biomedical responsibilities. Even though the agency will probably wish to continue to draw on many other sources for help in solving its biological problems, the presence of at least a small staff of highly qualified biologists and medical men is essential for the formulation of over-all policy, the direction of research and operations within the NASA, and the negotiation of satisfactory working agreements with other Government agencies and the military services.

For the next few years, and possibly indefinitely, the NASA will need to rely heavily on the military services for help in the technology or applied aspects of aeromedicine. For reasons outlined above, the military services presently appear to possess a capability in excess of their own need and are anxious to cooperate in every possible way. The committee was impressed by the ease with which NASA has arranged cooperative research between individual and small groups of workers in the military laboratories. It is apparent that personnel may be lent from one agency to another, apparatus may be transferred or time made available at military installations with a minimum of administrative difficulty so long as the scale of the operation is kept reasonably small. All those who provided information for the committee were unanimous on this point.

The situation is far more dubious with respect to large or long-continued programs involving extensive transfer of personnel, facilities, or funds. Complex contracts of this character would doubtless have to be channeled to rather high levels in the Department of Defense with concomitant delays and uncertainties. A more serious question involves the overall Government policy in relation to the budget. To what extent will or should the Bureau of the Budget or the Congress permit the transfer of segments of the NASA budget to other agencies for the execution of NASA directed and supervised objectives? To put the question another way, how far can the military services go in justifying the salaries and allowance of military personnel a substantial part of whose time is spent on civilian missions?

Another difficulty arises from the fact that the apparent excess of space medical capability now available in military establishments may be temporary. How far the present cordial cooperativeness of military personnel is dependent on this temporary excess is difficult to determine, but the possibility cannot be ignored. The present situation is at best an unstable one. Either of two things may happen. The military decision to rely heavily on unmanned ballistic or guided vehicles may become more firmly established. This will lead to a further decline in military requirements for aeromedicine with concomitant budget cuts for the support of aeromedical installations. Conversely, and in the opinion of the committee more probable, present skepticism in regard to the utility of manned military vehicles will gradually disappear and the services will be provided with increased funds for research in space medicine. In either case, the excess military capability now available to NASA is likely to decline if not completely disappear.

Faced by these considerations the committee makes the following recommendations:

1. The Applied Medicine and Biology Section of the proposed Office of the Life Sciences should, in the immediate future, make the fullest possible use of the excellent facilities and personnel for biomedical research now available in the military services. The exact mechanisms for this cooperation must be worked out in large part by the Administrator, the Director of the Life Sciences, and his staff together with the proposed section on extramural research. In many cases, the necessary arrangements can be based on informal agreements to assign personnel or make facilities available. In others, formal contracts guaranteeing definite sums of money over stated periods of time will be necessary. In order to facilitate the negotiating of such arrangements, additional liaison machinery should be set up between the Department of Defense and NASA in the Life Sciences. This might well be a committee composed of the Directors of Bioastronautics of the Air Force and Navy, the Director of the Office of Life Sciences, and the Assistant Director for the Applied Medicine and Biology Programs of NASA. This committee should be empowered by general directives from the Department of Defense and NASA to work out contractual and other arrangements for the conduct of research and development in aerospace medicine.

A Civilian-Military Liaison Committee is in existence to arrange for cooperative interagency undertakings. It is felt, however, that astromedical matters involve quite different considerations from those regularly dealt with by the Civilian-Military Liaison Committee. The amounts of money involved are much smaller and other factors in situation are such as to make it unlikely that the human problems of space flight will get the attention their importance merits unless they are dealt with by a specially constituted group.

2. As soon as possible the NASA Applied Medicine and Biology Section should develop an in-house capability for research and development as part of the intramural program recommended in section IV-B.

The exact extent of in-house capability cannot be foreseen at this time. In view of the uncertain availability of military facilities in which much of the immediate research program must be developed, it seems wise to recommend that the long-term program include facilities for the study of every aspect of bioastronautics except those which involve heavy expenditures for special items of equipment.

3. The provision of adequate access to large and expensive apparatus raises special problems. At the present time, the most notable example is the human centrifuge for simulating space flight problems at Johnsville. In most instances, one such installation should be enough to serve the national interest, if proper arrangements are made in advance for its construction and utilization. The present practice is that one or another of the services develops a given installation to meet its own needs and then invites or allows the other services to use it on the basis

of ad hoc agreements. The committee wishes to recommend that in the future such facilities be planned and operated on an explicit NASA-interservice basis. Various administrative patterns may be thought of to achieve this end. In some cases the facility might be set up as an independent authority with its own budget to provide research service to other government agencies such as the Bureau of Standards does now. In other instances the facility could be held and operated by a NASA-interservice committee with a budget provided by one or more of these services represented on the committee. This pattern has worked well for the Armed Forces Institute of Pathology.

E. Training

In common with every agency of Government and industry which utilizes and depends upon scientific and technical specialists, NASA has a stake and responsibility in the education and training of such men and in the continued supply of scientific manpower generally. An agency which attempts completely to fulfill its responsibilities in this area may recognize a dual nature in these responsibilities. It is, of course, necessary to create and maintain a cadre of scientists properly equipped with the specialized knowledge, skills, motivation, and philosophy which are required for the particular mission, but it is also important that this be done without depletion of other important activities which include: national defense, health, aviation medicine, and the basic biological, medical, and behavioral disciplines upon which these areas depend.

The committee recommends that NASA take immediate steps to initiate a diversified program of training and the support of training administered by the Office of Life Sciences through the Section on Extramural Activities and that in the planning of such a program attention be given to the following types of activities:

1. Post graduate fellowships or traineeships at NASA installations, at space biology institutes, or in certain laboratories of the Armed Forces, the United States Public Health Service and other governmental operations, or at appropriate departments in universities here and abroad for individuals, including members of NASA staff, foreign scientists and others, who have chosen a career in astrobiology, space medicine, or immediately related fields.

2. Training grants to appropriate institutes or university departments to support existing teaching activities or initiate new ones in areas of general or special relevance to the NASA Life Sciences Division.

3. Short-term visiting scientist appointments (from 2 months to 2 years) to permit qualified scientists from this country and abroad to utilize certain of the special facilities of NASA or the Armed Forces in research of relevance to the life sciences program.

F. Communication and information

The committee, in common with scientists generally, believes that the primary purpose of science, which is to increase man's understanding of the universe, is best fulfilled by free exchange of scientific findings, information, and criticism among all scientists. The Congress, in establishing this agency, declared "that it is the policy of the United States that activities in space should be devoted to peaceful purposes for the benefit of all mankind." To this end, the committee recommends that NASA give serious thought to those mechanisms and guarantees which will facilitate free scientific interchange with respect to the life sciences program. Among those which the committee has considered and which it supports are the following:

1. Judicious use of travel funds to permit the exchange of information between individual scientists, or among scientists at national or international meetings and symposia without arbitrary restrictions but guided by the value of such interchange to the advancement of knowledge.

2. The sponsorship by NASA of bulletins, journals, and of conferences, meetings and symposia on topics or in fields where such media or opportunities for exchange of information would be of value.

3. The establishment of a policy of the free reporting of all scientific information obtained in the life sciences through the extramural or intramural operations of NASA in the open scientific literature. Security regulations with respect to personnel or publications and in the areas of grants, contracts and fellowships must be exercised with great caution and limited to those specific projects where a direct relationship to national security can be clearly demonstrated.

G. NASA life sciences facilities as a public trust

Although much basic research related to problems of space can be conducted in appropriate facilities on earth, it is apparent that many observations must be made in space vehicles. The study of the effect of weightlessness is an obvious example; spectrographic analysis of the surface of the planets from platforms high above the disturbing influences of the earth's atmosphere is another. For some time to come, the space available for scientific instruments in space vehicles is likely to be strictly limited. At the present time almost all such space and bandwidths available for telemetry are being absorbed by the equipment necessary to monitor the function of the vehicle itself or to make limited physical observations of its immediate environment. Prospective improvement of propulsion systems will soon provide more commodious vehicles, but for years to come the supply of facilities is likely to be far less than the demand. Proper allocation of such space facilities will be very difficult to arrange and certainly cannot much longer be left solely to the good will of those responsible for the design and operation of launching equipment, or to random excitement as to who can inject the largest mammal into orbit.

Attention may be drawn to the fact that at present two great powers between them enjoy a monopoly on operations in space. Although this list may be expanded somewhat in years to come, the extensive resources needed to support such missions make it likely that they can be carried out only by the very largest nations. It is a tradition of long standing in the United States that a monopoly position carries with it the obligation to conduct affairs with due regard to the public interest. In the present instance the monopoly is essentially worldwide, since it includes the control not only of the vehicles themselves but of the most suitable launching sites throughout the world. It follows that these facilities should be administered so far as it is possible in the public interest of the world at large. The committee is heartened by the provisions which the NASA has made towards greater international cooperation. As man stands before the moment when at last he may break the bonds which have chained him to a single planet, it seems fitting and proper to ensure that all mankind, and not two nations alone, should have the opportunity to meet this momentous challenge.

APPENDIX L

Research grants and contracts (initiated from Oct. 1, 1959, through Mar. 31, 1960)

[Contracts have prefix NAW or NASw; grants have prefix NSG; when number is not given, action was incomplete at time of writing. Earlier grants and contracts are listed in app. L of the 2d semiannual report to the Congress]

Grant or contract No.	Organization and purpose	Principal investigator	Duration	Amount
CALIFORNIA				
NSG 56-60-----	California Institute of Technology----- Study of problems of lunar and planetary exploration.	Harrison Brown-----	12 months---	\$115,000
NASw-10----- (continuation)	University of California----- Plastic properties of ceramic systems.	J. A. Pask-----	---do-----	28,000
	Rand Corp----- Investigation of charged particles and fields in space.	E. H. Vestine-----	18 months---	114,441
NASw-103-----	Rand Corp----- Research and study on specific economic and international aspects of space technology and related activities.			223,100
	Stanford Research Institute----- Investigation of nonlinear differential equations as applied to celestial mechanics.	J. L. Brenner-----	12 months---	33,030
NASw-142-----	Stanford University----- Investigation of very low frequency radio propagation utilizing satellite data.	R. A. Helliwell-----	---do-----	122,620
NSG 47-60-----	Stanford University----- Theoretical and experimental investigation of higher order nonlinear control systems, including investigation of "quasi optimum" control systems. (Continuation of NAW-6555.)	I. Flugge-Lotz-----	---do-----	18,700

Research grants and contracts (initiated from Oct. 1, 1959, through Mar. 31, 1960)—
Continued

[Contracts have prefix NAW or NASw; grants have prefix NsG; when number is not given, action was incomplete at time of writing. Earlier grants and contracts are listed in app. L of the 2d semiannual report to the Congress]

Grant or contract No.	Organization and purpose	Principle investigator	Duration	Amount
CALIFORNIA—continued				
NsG 52-60	Stanford University Convection heat transfer in annular passages with and without asymmetric heating and eccentricity. (Continuation of NAW-6554.)	W. M. Kays and W. C. Reynolds.	24 months	\$72,607
NsG 53-60	Stanford University Investigation of a technique for the production of metallurgical structures containing uniformly dispersed stable particles. (Continuation of NAW-6558.)	R. A. Huggins	12 months	31,000
	Stanford University Techniques for experimental exobiological research.	J. Lederberg	do	40,875
COLORADO				
	Colorado State University Pathogen-free plants in a microcosm. II. Effects of high intensity light on plant growth.	R. Baker et al	24 months	65,700
NsG 50-60	University of Denver The study of ionization phenomena in hydrogen, nitrogen, and oxygen by high velocity atomic and molecular beams. (Continuation of NASw-13.)	N. Utterback	36 months	119,271
NsG 61-60	University of Denver (Colorado Seminary) The scavenging of tungsten and molybdenum with selected rare earths.	D. T. Klodt	12 months	47,810
NsG 65-60	University of Denver Symposium on atomic and molecular beams.	G. H. Miller		1,300
CONNECTICUT				
	Yale University I. Atomic frequency standards. II. Atomic and molecular collision cross sections. (Continuation of NsG 1-59.)	Hughes and Robinson	24 months	220,008
	Yale University Investigation of polarization of nonthermal radiation from Jupiter.	Harlan J. Smith	do	80,042
DISTRICT OF COLUMBIA				
NASw-96	Brookings Institution Design of a comprehensive and long-term program of research and study re the social, economic, political, legal, and international implications of the use of space for peaceful and scientific purposes.		12 months	96,000
NsG 60-60	Catholic University of America Flow and fracture of high strength materials. (Continuation of NASw-2.)	E. P. Klier	24 months	62,600
NTF 104	National Academy of Sciences-National Research Council Activities of the Space Science Board.			69,600
NTF 97	National Bureau of Standards Effect of surface reactions on fatigue failures. (Continuation of NBS-34.)	B. Holshouser	12 months	26,000
	Smithsonian Institution Tekite collection and study.	E. P. Henderson	24 months	12,000
FLORIDA				
NsG 67-60	University of Florida Negative ion formation in gases.	E. E. Muschlitz, Jr.	12 months	55,000
GEORGIA				
	Georgia Institute of Technology Preparation of a mathematical procedure for determining the drag forces acting on an artificial satellite.	E. L. Davis	do	40,000

Research grants and contracts (initiated from Oct. 1, 1959, through Mar. 31, 1960)—Continued

Contracts have prefix NAW or NASw; grants have prefix NsG; when number is not given, action was incomplete at time of writing. Earlier grants and contracts are listed in app. L of the 2d semiannual report to the Congress]

Grant or contract No.	Organization and purpose	Principle investigator	Duration	Amount
ILLINOIS				
NASw-135.....	University of Chicago..... Explorer VI data reduction and analysis for Experiment No. 1.	L. M. Biberman.....	6 months....	\$38,525
NASw 55-60....	University of Illinois..... Experiment to determine the effect of aurora on radio signals from satellites. (Continuation of NsG 24-59.) Supplement.	G. W. Swenson, Jr.....	.....do.....	11,073
IOWA				
NsG 62-60.....	Iowa State College..... Application of blade-element techniques to the design and performance prediction problems for axial flow pumps. (Continuation of NAW 6518.)	G. K. Serovy.....	12 months....	11,430
MARYLAND				
	University of Maryland..... Theoretical studies on interplanetary gas and dust.	S. F. Singer and E. J. Opik.....	36 months....	97,000
	University of Maryland..... Investigation of phycophysiology in controlled environments.	R. W. Krauss.....	.....do.....	216,000
MASSACHUSETTS				
	Bolt, Beranek & Newman, Inc..... Development of analysis techniques for determining human transfer functions.	J. I. Elkind.....	12 months....	46,620
	Boston University..... Investigation of the nature and origin of tektites. (Continuation of NsG 21-59.)	G. S. Hawkins.....	.....do.....	11,803
	Harvard University..... Study of infrared instrumentation for thermal photography of the Moon.	D. H. Menzel.....	24 months....	103,587
NASw-130.....	Massachusetts Institute of Technology..... Study of the navigation, guidance, and control of an interplanetary vehicle.	M. B. Trageser.....	3 months....	50,000
	Massachusetts Institute of Technology..... Gamma ray instrument packages for balloon and satellite flights. (Continuation of NASw 37-59.)	W. L. Kraushaar.....	12 months....	225,830
	Massachusetts Institute of Technology..... Studies of satellite and space probe communication systems.	T. Rogers.....	.....do.....	150,000
	Massachusetts Institute of Technology..... Satellite gravitational red shift experiment. (Continuation of NASw-33.)	J. B. Wiesner.....	9 months....	75,000
NsG 55-60.....	Smithsonian Institution, Astrophysical Observatory..... Research and design studies on an astronomical telescope for an orbiting stabilized platform. (Continuation of NsG 7-59.)	F. L. Whipple.....	7½ months..	199,927
	Smithsonian Institution, Astrophysical Observatory..... Design and construction of equipment for an ultraviolet sky survey to be conducted from a stabilized satellite. (Continuation of NsG 51-60.)	.....do.....	9 months....	125,000

Research grants and contracts (initiated from Oct. 1, 1959, through Mar. 31, 1960)—
Continued

[Contracts have prefix NAW or NASw; grants have prefix Nsg; when number is not given, action was incomplete at time of writing. Earlier grants and contracts are listed in app. L of the 2d semiannual report to the Congress]

Grant or contract No.	Organization and purpose	Principle investigator	Duration	Amount
MICHIGAN				
NASw-5 (amendment).	University of Michigan..... Mechanism of fracture during working or during fracture by creep. (Increase in scope of NASw-5.)	J. W. Freeman.....	-----	\$6,000
NASw-133.....	University of Michigan..... Measurement of atmospheric pressure in the region between the earth and the Moon.	N. W. Spencer.....	12 months...	50,000
NASw-138.....	University of Michigan..... Rocket grenade instrumentation packages for synoptic measurements of the properties of the upper atmosphere. (Continuation of NASw-4.)	L. M. Jones.....	---do---	195,550
NASw-140.....	University of Michigan..... Techniques for radiation measurements from satellites in the visible and near infrared regions of the spectrum.	F. L. Bartman.....	---do---	270,000
	University of Michigan..... Charged particle measurements including electron temperature and energy distribution and electron and ion density at altitudes above 100 km. by the Langmuir probe technique.	N. W. Spencer.....	---do---	117,500
	University of Michigan..... A study of structural dynamic problems using the electronic differential analyzer. (Continuation of NAW 6557.)	D. T. Greenwood.....	---do---	19,000
MINNESOTA				
	University of Minnesota..... Closed ecological systems studies. (Continuation of NASw-70.)	H. M. Tsuchiya and A. M. Brown	-----	180,000
MISSISSIPPI				
	Mississippi State University..... Biochemical study of mixed culture algal prototypes in a closed ecological system.	R. G. Tischer.....	36 months...	55,345
NEBRASKA				
	Nebraska Historical Society..... Examination of newspapers covering the period of the 1913 meteor shower.	-----	1 month.....	100
NEW HAMPSHIRE				
	University of New Hampshire..... Measurement of the magnitude and direction of the earth's magnetic field at satellite altitudes.	L. J. Cahill.....	12 months...	31,280
NEW JERSEY				
NTF 90.....	Princeton University..... The use of television techniques with telescopes above the atmosphere.	M. Schwarzschild.....	---do---	110,000
NEW YORK				
	Columbia University..... The buffering of carbon dioxide in the dog during prolonged hypercapnia.	G. G. Nahas.....	---do---	14,500
	New York University..... Theoretical research on molecular quantum mechanics and transport properties of diatomic molecules.	R. C. Sahni.....	---do---	50,900
Nsg 48-60.....	Rensselaer Polytechnic Institute..... Investigation of the properties of gaseous plasmas by microwave techniques.	E. H. Holt.....	---do---	45,960
	University of Rochester..... Spectrophotometric techniques for satellite observations of the sun at 10-200 angstroms.	M. P. Givens.....	3 months...	9,980

Research grants and contracts (initiated from Oct. 1, 1959, through Mar. 31, 1960)—Continued

[Contracts have prefix NAW or NASw; grants have prefix NsG; when number is not given, action was incomplete at time of writing. Earlier grants and contracts are listed in app. L of the 2d semiannual report to the Congress]

Grant or contract No.	Organization and purpose	Principle investigator	Duration	Amount
NORTH CAROLINA				
NsG 59-60	North Carolina State College. Condensation with condensate removal by centrifugal force.	K. O. Beatty	36 months	\$66,500
OHIO				
NASw-71 (amendment)	Battelle Memorial Institute. Analysis of reactor fuel specimens. (Increase in scope of contract NASw-71.)	W. H. Goldthwaite		5,500
	University of Cincinnati. Investigation of acceleration protection by immersion during hypothermic suspended animation.	B. Black-Schaffer	36 months	71,000
	Ohio State University. Research on receiver techniques and detectors for use at millimeter and submillimeter wavelengths.	T. E. Tice	12 months	20,000
OKLAHOMA				
	Oklahoma State University. Experiments on electrical conductivity and ion density in the upper atmosphere.	R. F. Buck	6 months	48,175
PENNSYLVANIA				
NTF-100	Franklin Institute, Office of Naval Research. Joint Agencies Program of research on gas-lubricated bearings. (Continuation of HS-82.)	D. D. Fuller	12 months	20,000
NsG 57-60	Mellon Institute. Research on the composition and structure of tektites and meteorites.	A. J. Coehn and T. B. Massalski	24 months	103,000
NsG 66-60	Pennsylvania State University. Theoretical study of stress penetration waves and impact damage in plates. (Continuation of NASw-14.)	W. Jaunzemis	do	33,604
TEXAS				
NASw-136	Chance Vought Aircraft, Inc. Principles of the twin gyro reaction attitude controller.	J. F. Reagan	5 months	29,791
	Grumman Aircraft Engineering Corp. Experimental and theoretical research on an improved particle charging technique.	J. L. Hyde	7 months	28,897
	Rice Institute. Research on physics of solid materials including study of the behavior of solids at high temperature. (Continuation of NsG-6-53.)	F. R. Brotzen	24 months	300,000
	Southwest Research Institute. Trace contaminants in enclosed system.	W. E. Thompson	12 months	40,000
	Southwest Research Institute. Studies of fuel sloshing by use of small models.	H. N. Abramson	do	42,082
	University of Texas. Study and evaluation of radiation equipment and problems in the millimeter and submillimeter wavelength regions.	A. W. Straiton	do	7,000
WISCONSIN				
NASw-65 (amendment)	University of Wisconsin. Measurements from Explorer VII and future satellites.	V. E. Suomi	6 months	100,000
FOREIGN—NEW ZEALAND				
NsG 54-60	University of Auckland. Investigation of the propagation of radio signals from artificial satellites.	H. A. Whale	12 months	7,000

APPENDIX M

R. & D. contracts or amendments thereto of \$100,000 and over shown by program (awarded Oct. 1, 1959, through Mar. 31, 1960)

ACTIVITY: NASA HEADQUARTERS

Program	Contract No.	Purpose	Contractor	Approximate obligations ¹
Scientific investigations in space: Sounding rockets	NASW-31 (HS-69)	Instrument 2 Aerobee-Hi rockets for neutron intensity measurements	New York University	\$100,000
	NASW-215 (HS-215)	Study winds, diffusion and expansion of gases in the upper atmosphere.	Geophysics Corp. of America	290,000
Scientific satellites	NASW-37 (HS-131)	Gamma ray detection instruments and prototype for 1 satellite vehicle.	Massachusetts Institute of Technology.	300,000
	(HS-480)			
	NASW-107 (HS-320)	Research on solid state photo detectors.	University of Rochester	120,000
	NASW-89 (HS-271)	Study of solar ultraviolet radiation from both rockets and satellites.	University of Colorado	110,000
	NASW-142 (HS-520)	Processing data obtained from Able III and Explorer VI.	Stanford University	120,000
	NTF-53 (HS-178)	Radio beacons for satellites	AOMC (Army)	219,000
	NTF-12 (HS-1)	Radiation payload for Juno II, 19a.	do.	990,000
	(HS-46-304-325-332-357-392-426)			
	(HS-515)			
	NTF-17 (HS-6-194-361-409)	1 earth satellite (including 1 Thor-Able booster and 1 Thor to be used in Delta program). (See also lunar and planetary exploration.)	BMD (ARDC-Air Force)	200,000
	NTF-61 (HS-21-301-333-404)	5 Juno II boosters.	AOMC (Army)	3,580,000
	NASW-113 (HS-273)	Study of satellite-borne solar pointing control.	Ball Bros. Research Corp.	250,000
	NTF-80 (HS-374)	Initiate work on gamma ray astronomy satellite.	AOMC (Army)	700,000
	(HS-501)			
	NTF-81 (HS-375)	Initiate work on ionosphere measurements satellite.	do.	590,000
	(HS-498)			
	NTF-83 (HS-390)	Determine physical properties of the ionosphere.	Bureau of Standards (Commerce)	130,000
	NTF-84 (HS-389)	Provide tables of electronic densities versus altitude.	do.	100,000

Lunar and planetary exploration	NASW-124 (HS-403)	Study of chemical physics of planetary atmospheres.	Geophysical Corp. of America	150,000
	NTF-60 (HS-414)	Develop television system	ONR (Navy)	110,000
	NASW-81 (HS-171)	Lunar seismograph system	California Tech.	130,000
	NASW-6 (HS-41) (HS-412) (HS-309)	Deep space study	JPL (California Tech)	21,660,000
	NASW-17 (HS-51)	Space probe instrumentation. (See also scientific satellites.)	Iowa State University	290,000
	NASW-24 (HS-53)	Cosmic ray instrument.	University of Chicago	300,000
	NASW-82 (HS-180)	Lunar seismograph system	Lamont Geological Observatory (Columbia University).	120,000
	NASW-75 (HS-212)	Design, test, and construct prototype to measure plasma density and energy	Massachusetts Institute of Technology	100,000
	NTF-17 (HS-6-44)	1 lunar orbiter and 1 deep space probe. (See also scientific satellites.)	BMD (ARDC-Air Force)	4,560,000
	(HS-194-300-334-361-368-373-387-523)			
Satellite applications:				
Meteorology	NTF-60 (HS-310) (HS-471)	Meteorological analysis for Fiscal Year 1960	U.S. Weather Bureau	600,000
Communications	NASW-6 (HS-340) (HS-412)	Purchase of items for the launching of communications satellite in March 1960.	JPL (California Tech)	720,000
Vehicle systems technology	NASW-6 (HS-323-411-412)	Conduct of research.	do	4,140,000
	NTF-55 (HS-347)	To extend study on use of Saturn for lunar and planetary missions.	AOMC	150,000
Space propulsion technology:	NASW-6 (HS-412)	Conduct of research.	JPL (California Tech)	2,060,000
Solid rockets	NASW-6 (HS-58)	do	do	2,990,000
Liquid rockets	(HS-412) NASW-16. (HS-10) (HS-356)	1½ million pound thrust rocket engine.	Rocketdyne Division of North American Aviation, Inc.	23,000,000
Space power technology.	NASW-28. (HS-76) (HS-197-347-418-419-420-421)	Feasibility of liquid fluorine-liquid hydrogen in a rocket engine.	Bell Aircraft Corp.	120,000
	NASW-6 (HS-412)	Conduct of research.	JPL (California Tech)	1,060,000
Nuclear systems technology.	S-2494-G	Obtain services and materials necessary to determine physical properties of hydrogen.	National Bureau of Standards	150,000
	NTF-21 (HS-15) (HS-413)	Rover program	Atomic Energy Commission.	1,450,000
	NASW-114 (HS-225)	Evaluation of radiation effects on materials operating in Cryogenic temperatures.	Lockheed Aircraft Corp.	1,000,000

See footnotes at end of table, p. 179.

R. & D. contracts or amendments thereto of \$100,000 and over shown by program (awarded Oct. 1, 1959, through Mar. 31, 1960)—Continued

ACTIVITY: NASA HEADQUARTERS—Continued

Program	Contract No.	Purpose	Contractor	Approximate obligations ¹
Vehicle development: Delta.....	S-4631-G NASW-38 (HS-90) (HS-241) (HS-388-459-476-496) NTF-45 (HS-324) (HS-435) NASW-30 (HS-103) (HS-274) (HS-363) (HS-428-429) (HS-440) NTF-57 (HS-302-362-458-481) NTF-96 (HS-458) S-4644G	To reimburse Air Force for shipment of Delta vehicle hardware. Delta launch vehicle..... Operation of computers and post flight analysis of data for 7 Delta launchings. Development of liquid propellant rocket engine and ground support equipment and second stage testing.	U.S. Air Force..... Douglas Aircraft Co..... BMD (Air Force)..... General Electric Co.....	\$130,000 10,200,000 500,000 1,090,000
Vega.....				
Centaur.....		Provide for work on Centaur for the fiscal year 1960 (contract AF 18 (600)-1774).	ARDC (Air Force)..... do.....	1,500,000 19,000,000
Saturn.....		Continue work on Centaur (contract AF 18 (600)-1774)..... To permit acceleration of the Saturn vehicle development program. To initiate NASA Agena-B vehicle program. R. & D. on improved tracking and receiving equipment.....	AOMC..... ARDC..... JPL (California Tech).....	1,450,000 1,100,000 2,280,000
Vehicle procurement. Supporting activities.....	S-4601G NASW-6 (HS-135) (HS-412) HS-32..... (HS-330-331-378) NASW-68 (HS-227) NTF-72 (HS-335)	Tracking and data reduction services to end of fiscal year 1960. Use of radio telescope..... Support of Fort Churchill through September 1959.	Smithsonian Institution..... University of Manchester..... Research and development (Army).....	2,110,000 180,000 250,000

ACTIVITY: LANGLEY RESEARCH CENTER

Advanced research program: Support of NASA plant.....	NA1-3200.....	Sensor and support equipment.....	Northrop Aircraft, Inc.....	\$260,000
	NAS1-473.....	Energy storage capacitors.....	Westinghouse Electric Corp.....	110,000
	NA1-3420.....	Spherical rocket motors.....	Thiokol Chemical Corp.....	110,000
	NAS 5-57.....	Deconstruct system, design of transport vehicles and launcher and 1 control study (Little Joe).....	North American Aviation.....	240,000
Manned space flight.....	L-45, 931G.....	Castor development.....	Department of Army, Ordnance Corps.....	270,000
	L-74, 110G.....	Services at Bermuda (Project Mercury).....	Federal Aviation Agency.....	160,000
	L-75, 876G.....	Services at Kanai, Hawaii (Project Mercury).....	Navy Department, Bureau of Naval Weapons.....	230,000
	NAS1-430.....	Port-to-port transportation charges (Project Mercury).....	Western Electric Co.....	130,000
Vehicle development: Scout.....	NAS1-249.....	Scout IV vehicles and launcher.....	Chance Vought Aircraft Inc.....	120,000
	NAS5-61.....	2d stage reaction control system.....	Minneapolis-Honeywell Regulator Co.....	330,000
	L-35-931G.....	Castor rocket.....	Department of Army, Ordnance Corps.....	210,000
	NAS1-585.....	Fabricate rocket motors and test jet vane assembly.....	Aerojet-General Corp.....	240,000
Supporting activities.....	S-1010G.....	X-254 motors.....	Department of Navy, Bureau of Ordnance.....	420,000
	NAS1-229.....	Consulting services (Project Mercury).....	Massachusetts Institute of Technology.....	590,000
	L-77, 203G.....	10 rocket motors.....	U.S. Army Missile Command.....	490,000
	L-72, 505G.....	19 rocket motors.....	Bureau of Ordnance, Department of Navy.....	470,000
Vehicle Development: Anticipated Reimbursements, Scout.....	NAS5-61.....	Study and fabrication of standard scout guidance and control system.....	Minneapolis-Honeywell Regulator Co.....	770,000
	NAS1-553.....	Modify airframe.....	Chance Vought Aircraft, Inc.....	860,000
	NAS1-585.....	Algeol rocket motors.....	Aerojet General Corp.....	710,000

ACTIVITY: AMES RESEARCH CENTER

Aeronautical and Space Research: Support of NASA Plant.....	NAS2-261.....	Air density measuring instrument.....	Vidya, Inc.....	\$260,000

ACTIVITY: LEWIS RESEARCH CENTER

Advanced research programs: Support of NASA plant.....	NAS3-021.....	2-phase sodium loop.....	MSA Research Corp.....	\$110,000

See footnotes at end of table, p. 179.

R. & D. contracts or amendments thereto of \$100,000 and over shown by program (awarded Oct. 1, 1959, through Mar. 31, 1960)—Continued

ACTIVITY: GODDARD SPACE FLIGHT CENTER

Program	Contract No.	Purpose	Contractor	Approximate obligations ¹
Advanced research programs: Support of NASA plant.....	GS-1.....	For services in connection with the tenancy of elements of GSFC at NRL.	NRL (ONR-Navy).....	\$2,500,000
	S-2019.....	For services, time, and material to accomplish shop work orders.	Naval Weapons Plant.....	330,000
Scientific investigations in space: Sounding rockets.....	GS-1.....	Research and development services in connection with the tenancy of elements of the GSFC at NRL.	NRL (ONR-Navy).....	2,600,000
	GS-22.....	Vacuum calibration system, and for obtaining a working prototype of a new low-pressure detector.	National Research Corp.....	110,000
	NAS5-225.....	Procure 9 solar beam experiment rocket instrumentation systems.	Cook Research Laboratory Division.....	230,000
	GS-134.....	Multichannel pulse height analyzer for satellite and space probe use.	Radiation Instruments Development Laboratory.....	110,000
	NAS5-23 (W).....	Development of aluminum cased Nike-Asp sounding rocket vehicle.	Cooper Division Corp.....	330,000
	GS-41.....	Procure motors required for 4 Argo D-8 vehicles, 1 Argo D-8 sounding rocket vehicle, vehicle hardware, analyses, reports, liaison, etc.	Aerolab Development Corp.....	210,000
	NAS5-202.....	Research and development services in connection with the tenancy of elements of the GSFC at NRL.	NRL (ONR, Navy).....	2,000,000
	GS-58.....	do.	do.....	500,000
	NAS5-20.....	Services, labor, and materials for the construction and completion of a radio tracking station.	Jones-Mahoney Corp.....	110,000
	GS-93.....	Alterations and repairs to building 6, Bellevue Annex, Naval Gun Factory.	Charles H. Riddle Co.....	130,000
Scientific satellites Lunar and planetary explorations Vanguard program.....	GS-1.....	Research and development services in connection with the tenancy of the GSFC at NRL.	NRL (ONR, Navy).....	2,000,000
	NAS5-7 (W).....	Fabrication of rocket-grenade instrumentation unit—Support of Project TIROS.	University of Michigan, Department of Army, Army Signal Corps.....	300,000
Satellite applications: Meteorology.....	NAS-115.....	Atlas boosters.	University of Michigan, Department of Army, Army Signal Corps.....	1,430,000
	HS-126.....	Redstone boosters.	BMD (Air Force).....	9,720,000
Manned space flight.....	HS-36.....	12 capsule systems, 12 ablation and 6 beryllium heat shields, 6 escape and 6 retrorocket systems, 9 adapter sections, 9 release mechanisms, a mockup of the capsule system.	AOMC (Army).....	6,150,000
	(HS-44)	Drop tests.	McDonnell Aircraft Corp.....	33,830,000
Vehicle development: Centaur.....	NAS5-59.....	Pressure suits.	U.S. Atomic Energy Commission.....	120,000
	S-1705(g).....	4 XLR-115-P-1 engines and necessary field service.	Bureau of Aeronautics (Navy).....	220,000
	S-1714(G).....	do.	WDZC-(AFBDM).....	1,500,000
	S-2111-G (HS-480).....	do.	do.....	do

Supporting activities.....				
GS-1.....		Research and development services in connection with the tenancy of elements of the GSEC at NRL.	NRL (ONR, Navy).....	1,600,000
NAS5-6(W).....		Call orders in connection with NASA satellite tracking program.	Bendix Radio, division of Bendix Aviation Corp	530,000
NASW-112.....		Computing services.....	CEIR.....	200,000
NTP-5.....		For services of computing systems.....	National Bureau of Standards.....	300,000
(G-5-100).....		Funding for communication radio teletype lines and equipment for 3d and 4th quarters fiscal year 1960.	Department of the Army.....	200,000
S-228G.....				

Amounts shown in this column on this and following pages represent obligations incurred during this report period only.
 The Vega program was canceled Dec. 11, 1959.

APPENDIX N

TABLE 4.—*Financial statement as of Mar. 31, 1960*
**APPROPRIATIONS AND TRANSFERS FOR THE FISCAL YEARS 1959
 AND 1960**

	Salaries and expenses	Research and development	Construction and equipment
Approved, fiscal year 1959:			
Appropriations to National Advisory Committee for Aeronautics: Independent Offices Appropriation Act, 1959; Public Law 85-844.....	\$78, 100, 000	-----	\$23, 000, 000
Appropriations to National Aeronautics and Space Administration: Supplemental Appropriation Act, 1959; Public Law 85-768.....	5, 000, 000	\$50, 000, 000	25, 000, 000
Second Supplemental Appropriation Act, 1959; Public Law 86-30.....	3, 186, 300	-----	-----
Transfers from the Department of Defense (72 Stat. 433).....	-----	154, 619, 532	-----
Total appropriations and transfers, fiscal year 1959.....	86, 286, 300	204, 619, 532	48, 000, 000
Approved, fiscal year 1960:			
Appropriations to National Aeronautics and Space Administration: Supplemental Appropriation Act, 1960; Public Law 86-213.....	91, 400, 000	335, 350, 000	3, 825, 000
Transfer from research and development to construction and equipment.....	-----	-15, 000, 000	15, 000, 000
Total appropriations and transfers, fiscal year 1960.....	91, 400, 000	320, 350, 000	188, 825, 000

† Additional appropriation of \$12,200,000 pending in H.J. Res. 621.

‡ Additional appropriation of \$10,800,000 pending in H.J. Res. 621.

STATUS OF 1959 FUNDS AS OF MAR. 31, 1960

	Allotments	Obligations	Expenditures
Salaries and expenses.....	\$86, 286, 300	\$85, 838, 156	\$84, 962, 241
Research and development:			
Advanced research programs.....	12, 282, 151	12, 259, 147	10, 470, 130
Scientific investigations in space.....	78, 687, 473	78, 456, 108	68, 089, 915
Satellite applications.....	4, 562, 356	4, 232, 040	2, 820, 724
Manned space flight.....	46, 410, 333	46, 276, 205	35, 367, 629
Vehicle systems technology.....	1, 902, 651	1, 453, 661	593, 651
Space propulsion technology.....	20, 404, 983	19, 636, 126	17, 722, 313
Vehicle development.....	37, 266, 911	36, 829, 892	21, 928, 962
Supporting activities.....	3, 095, 674	3, 062, 115	2, 705, 378
Total, research and development.....	204, 619, 532	202, 205, 377	149, 698, 702
Construction and equipment.....	48, 000, 000	29, 247, 710	18, 327, 325

STATUS OF 1960 FUNDS AS OF MAR. 31, 1960

	\$91, 400, 000	\$65, 585, 660	\$60, 202, 758
Salaries and expenses.....			
Research and development:			
Advanced research programs.....	27, 703, 630	18, 280, 116	8, 556, 776
Scientific investigations in space.....	75, 614, 000	51, 740, 327	10, 880, 806
Satellite applications.....	11, 100, 000	6, 918, 734	441, 447
Manned space flight.....	71, 390, 370	57, 467, 947	21, 634, 723
Vehicle propulsion technology.....	5, 187, 000	4, 004, 349	-----
Space propulsion technology.....	44, 177, 000	31, 233, 187	6, 220, 099
Vehicle development.....	57, 850, 000	52, 260, 630	9, 460, 026
Vehicle procurement.....	7, 360, 000	1, 100, 000	-----
Supporting activities.....	16, 238, 000	13, 249, 222	5, 826, 071
Bureau of the Budget reserve.....	3, 530, 000	-----	-----
Total, research and development.....	320, 350, 000	236, 254, 512	63, 019, 948
Construction and equipment.....	88, 825, 000	45, 920, 682	3, 151, 821